

**EXPERIMENTAL AND
RESEARCH STATION
CHESHUNT, HERTS**

ANNUAL REPORT

(THIRTY-NINTH YEAR)

1953

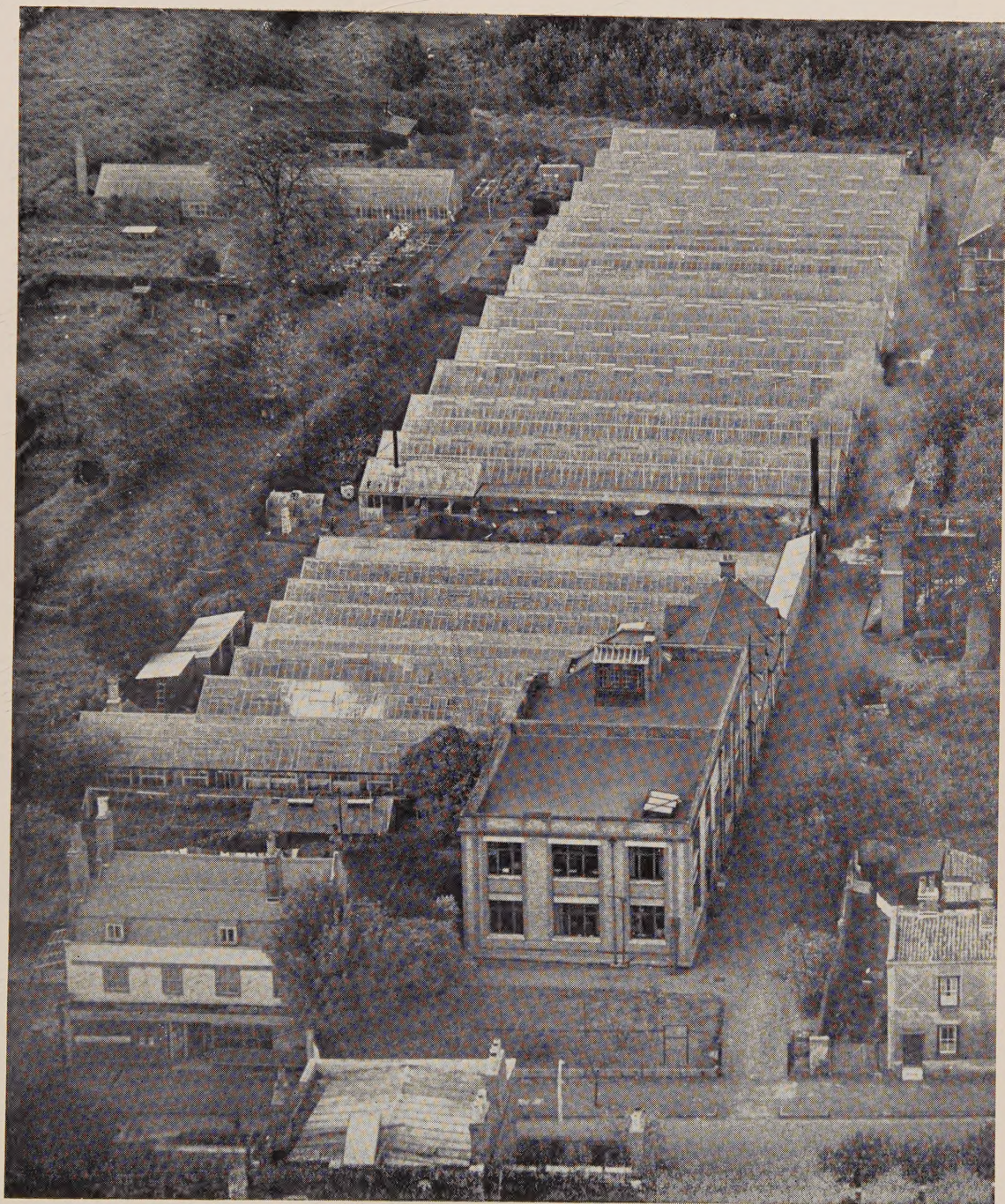
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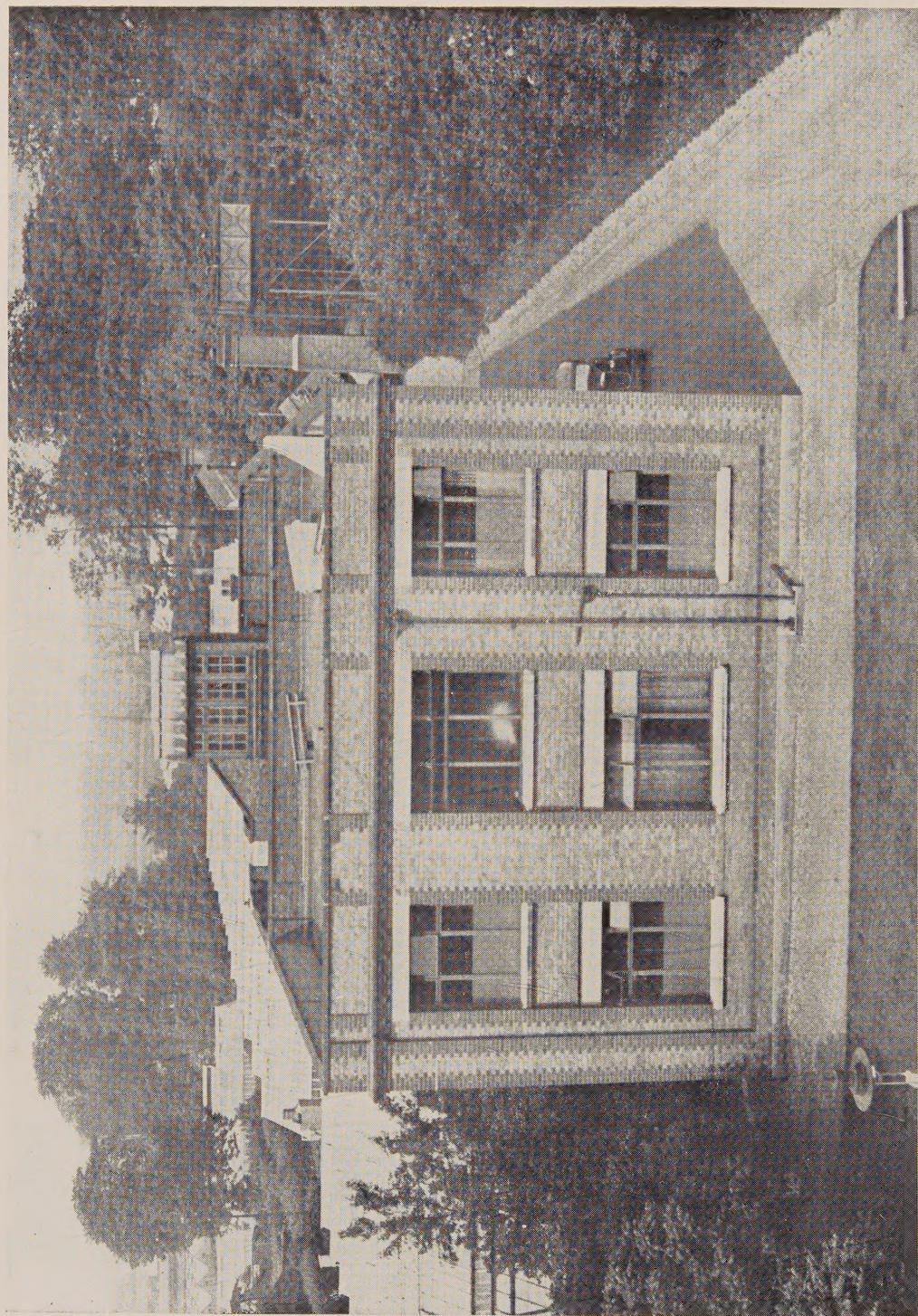
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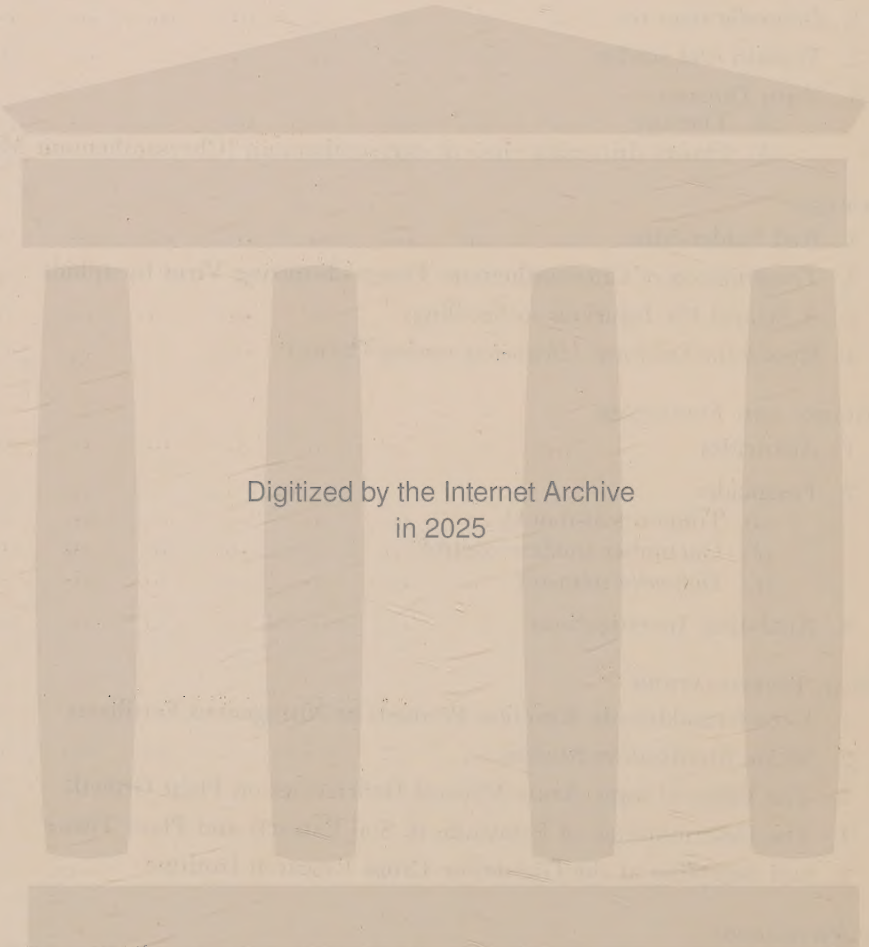
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INTRODUCTION

The work of the Research Station continues to progress steadily, but any attempt at extension has been prevented by lack of space.

It is a pleasure to report, however, that considerable progress has been made in developing the new site near Littlehampton. Rather more than an acre of experimental glasshouses has been erected together with certain ancillary buildings. A crop of tomatoes is being grown this year (1954) in every house for the purpose of detecting any variations in the land.

Work on the first laboratory block started early in January and the building should be ready for occupation towards the end of the year.

GLASSHOUSE EXPERIMENTS

Planting Density and Crop Yield of Tomatoes

In continuation of the investigation commenced in 1952 a slight modification of the present planting system was adopted. Four plots were planted at the normal density of 16,000 plants per acre. In two plots, alternate plants were "stopped" at the fifth truss and when the crop had been gathered the "stopped" plants were removed entirely from the soil thus reducing the density to 8,000 plants per acre. A sideshoot, however, from each of the remaining plants was trained into the space left by removing the adjacent plant.

The result showed a crop increase of 25 per cent., but this is so unexpected that arrangements have been made to conduct a large scale experiment in 1954.

Chloropicrin v. Formaldehyde

Owing to adverse conditions a correct comparison of the relative values of these substances as soil sterilizers failed in 1952, so the experiments were repeated in 1953. Growth in the experimental plots was uniform, and in the end there proved to be very little difference in crop yield. The roots were clean in both cases at the end of the season.

Steam v. Chloropicrin

These experiments were a repetition of those conducted in 1952. Once again there was no difference either in earliness of yield or in total crop produced.

Drip Watering

The drip watering experiment was continued with and without the addition of the soil conditioner Krillium. Once more there was no difference in crop production between the plants watered in the usual manner and those watering by the drip system; nor did the addition of Krillium have any effect.

Krillium

The effects of mixing Krillium with the soil, as observed in 1951 and 1952, occurred again. In the presence of the conditioner, water ran more easily through the soil and did not form puddles on the surface; also the soil retained its moisture longer. Unfortunately, however, an increased crop return was not recorded in any of the experiments.

The Omission of Lime and Phosphates

These experiments were started in 1947; so this year represents the seventh of the series. At last it seems that the omission of lime and phosphates is producing a lower crop yield.

Potentate and its hybrids

A considerable number of different strains of Potentate and related varieties were grown this year, also some twenty F.1. hybrids having Potentate as one parent. Selections have been made for future work in an attempt to produce a variety having all the good characters of Potentate and none of its bad ones.

Cucumbers

Fairly extensive trials were made with flat beds versus raised beds. Crop production was similar in each case, but picking was somewhat earlier in the raised beds. Doubling the amount of lime in the beds did not affect the yield but when lime was omitted and also when sulphur was added then the yield was decreased.

PLANT PATHOLOGY

Didymella Stem Rot

In an experiment in House 1, plots of 20 plants each were laid out and subjected to various treatments, following which they were watered with a spore suspension of *Didymella lycopersici*.

Digging in stable manure at the rate of 30 tons per acre either before or after steaming did not significantly increase the number of plants that developed lesions at the base of the stem. On unsteamed soil, whether receiving stable manure or not, the number of diseased plants was small, 5.6 per cent. compared with 41.5 per cent. on the steamed plots. The addition of certain soil organisms which might compete with *D. lycopersici* did not reduce the amount of infection.

Later in the season, lesions on the stem above soil level occurred despite care in watering. Losses of crop were due to the death of plants from both types of lesion as well as to *Botrytis* and *Verticillium* which together accounted for 5.5 per cent. of the deaths. On the steamed plots, the crops averaged about 75 per cent. of that on the uninoculated control (63.61 tons per acre). On the unsteamed plots, deaths due to disease were so small that the effect on the crop was negligible. A few fruit infected with *D. lycopersici* were picked but they only accounted for about 2 lbs. out of a total crop of 4,432 lbs.

Didymella lycopersici survived over the winter in the soil used for experiments in 1952, a small proportion of plants potted into it becoming diseased.

No connection could be found between the growth of *D. lycopersici* in certain soils and some of their chemical, physical and biological properties.

Tomato Root Studies

The relative effects of steaming and fallowing on the bacterial and fungal population of the soil and tomato rhizosphere have been compared. Soil counts of bacteria and fungi made at approximately monthly intervals from just after the plots were steamed until May showed that the populations of these two types of micro-organisms behave in completely different ways. Bacterial numbers did not vary significantly from plot to plot except immediately after steaming but a large increase in numbers was apparent in all plots during February after the soil had been flooded. This large bacterial population continued throughout the spring but had fallen in July. The fungal population showed a marked decrease in numbers throughout the whole year when plots were steamed, and the population in a plot which had not been steamed for four years was much higher than that of other plots. There was a gradual rise in numbers from December until April in the unsteamed series and a large increase between April and May. Between July and October when rhizosphere counts were taken the soil fungi numbers fell. The numbers in the steamed and unsteamed series did not seem to be altered by different fallowing treatments.

The rhizosphere populations were compared in July and October. Bacterial numbers in the outer rhizosphere and on the root surface showed no significant differences between treatments or from different sampling dates. The numbers of fungi in the outer rhizosphere were lower in the steamed plots, compared to the unsteamed plots, in July, but by October this difference had disappeared. On the root surface the numbers of fungi isolated from plants on different plots did not differ appreciably.

The amount of fungal penetration of the roots was high in the unsteamed plots both in July and October, but was not affected by different fallowing treatments. There was an increase in root infection from July to October in nearly all plots which was most marked in the unsteamed series.

Virus Diseases

There were further attempts at curing virus infected plants; some success was obtained by treatment with chlorophenoxy-acetic acids. The work on the flower distorting virus of the chrysanthemum was continued.

ENTOMOLOGY

Red Spider Mite (*Tetranychus telarius* L.)

Further information has been obtained as to the reactions of the mite when deprived of food but given access to water. An attempt has been made to observe the effects produced when mites were kept upon a plant exposed to a continuous current of air.

Flower-distorting Virus of Chrysanthemum

Experiments with three species of Aphids commonly found upon chrysanthemum have been carried out with a view to determining if any one of these insects might act as a vector of the virus.

So far as tests for the presence of the virus in plants used in the experiments have gone, it would appear unlikely that these particular species of aphids are concerned in transmitting the virus from plant to plant.

Root-knot Eel-worm (*Heterodera marioni* Cornu)

A small-scale experiment involving the treatment of the soil with Parathion is described. Some evidence was obtained to suggest that such treatment might be of some value in control of the pest.

Sciarid Flies

Observations have been recorded upon the habits and life-history of the Mycetophilid fly *Sciara modesta* Staeg., which has caused much injury to seedlings of tomato and nicotiana in the White-fly parasite breeding house at the Cheshunt Station.

By experiment, it was determined that drenching the soil of seed-boxes and pots with Parathion at a dilution of one part in 50,000 parts water killed all larvæ and some pupæ of the fly to a depth of at least one-half inch in the soil, and that this treatment in no way caused injury to, or retarded the growth of, the seedlings.

INSECTICIDES AND FUNGICIDES

Acaricides

Laboratory investigations of the relative ovicidal activities of chlorinated phenyl benzenesulphonates have been concluded and the results have been submitted for publication elsewhere. Differences in the activities of the five most ovicidally-potent compounds were not significant at the 95 per cent. kill level but replicated assays in which each compound, with the exception of 2 : 4-dichlorophenyl 2 : 4-dichlorobenzene sulphonate, was compared once with every other one, and four times in all, show that 4-chlorophenyl benzenesulphonate was equal or superior to 4-chlorophenyl 4-chlorobenzenesulphonate under the conditions of these tests.

The relative freedom from phytotoxic effects exhibited by these compounds is consequently of importance and preliminary tests with cucumbers has shown that there is little difference between the injurious action of 4-chlorophenyl benzenesulphonate (usually referred to as CPBS or PCPBS) and 4-chlorophenyl 4-chlorobenzenesulphonate (CPCBS) but that phenyl benzenesulphonate is very much less injurious to cucumbers.

Several newly-introduced compounds having two linked 4-chlorophenyl groups have been subjected to preliminary tests against red spider and have been found of sufficient merit for inclusion in future comparative trials. Unfortunately none of these compounds can be applied with safety to cucumbers.

Fungicides

The fungicidal activities of the chloroimide derivatives of certain chlorinated quinones have been determined in the laboratory.

Investigations of methods of controlling *Didymella* stem-rot of tomatoes have received increased attention. Many chemicals have been examined for eradicator action against stem lesions caused by this disease on pot plants and several which have shown promise were further tested on large plants grown under commercial conditions. A number of compounds synthesised in the laboratory have been examined in *in-vitro* tests against tomato-leaf mould (*Cladosporium fulvum*).

Trials were made in which a product, stated to contain 2 : 4-dinitrophenyl-6-capryl crotonate as the fungicidally active ingredient, was compared with a standard copper-petroleum mixture for the control of cucumber mildew—*Erysiphe cichoracearum*. The product gave control of the disease at a dilution equivalent to 0.013 per cent. active material, equal to that given by the standard

copper-petroleum spray. The "hardening" of cucumbers by the product at a dilution equivalent to 0.013 per cent. active material was less than that given by the standard copper-petroleum mixture and at 0.025 per cent. the adverse effect on cucumbers was about the same as that caused by the copper-petroleum spray under the conditions of these tests.

Analytical

The investigations of the factors affecting the possible danger from residues of parathion have been continued. The extent to which workers' hands may become contaminated with parathion through conducting cultural operations with plants recently treated with parathion smokes and aerosols, has been examined.

An analytical technique whereby parathion and certain isomers and analogues can be separated and estimated on a microgram scale has been studied and should help to establish the nature of any toxic hazard arising from the use of parathion under glasshouse conditions.

GENERAL CHEMISTRY

Nitrogenous Fertilizers

The preparation and testing of urea-formaldehyde materials as possible slow-acting nitrogenous fertilizers has been continued. The object of these investigations is to examine the possibility of preparing synthetic nitrogenous fertilizers which will decompose in the soil more slowly than natural organic materials such as hoof and horn. Numerous factors in the preparation of urea-formaldehyde materials influence the properties of the products, and extensive experimental work is thus necessary in the search for optimum conditions in the reaction of urea with formaldehyde. The testing of the products, also, is a matter for long-term experiments in which the conversion of urea-formaldehyde materials to inorganic forms of nitrogen is studied in the soil.

Considerable interest in urea-formaldehyde products as nitrogenous fertilizers is being shown in America, where leading manufacturers are examining methods of preparation and testing.

Steam Sterilization

The use of the autoclave as a means of partially sterilizing soil in the laboratory has been investigated. Special attention has been given to the effect of the duration and pressure of autoclaving on subsequent ammonia production. The amount of ammonia formed during the actual process of sterilization in the type of soil found in our glasshouses increased with the duration and pressure of autoclaving. In the case, however, of subsequent ammonification after the soil has cooled down, short steaming treatments were almost as effective as longer ones, and it was difficult to suppress ammonification completely. In more acid maiden soils greater differences between the various treatments were observed; in such soils ammonification was suppressed by the longer periods of autoclaving, and by short treatments at pressures in excess of 10 lbs. per sq. in.

The soil moisture content was also found to influence the amount of ammonia produced on incubation of the steamed soils, increasing moisture content being accompanied by increased ammonia production.

Mineral Deficiencies

Further studies of the visual symptoms resulting from mineral deficiencies have been made with various crops. Evidence has been obtained that splitting of the calyx in carnations is not directly associated with any particular mineral deficiency, but the possibility of some genetic factor influencing the results cannot be overlooked.

The main crop investigated was cyclamen. The symptoms of malnutrition were found to be more difficult to identify than in the subjects studied during previous years.

Some effects on tomato plants due to the omission of potassium, calcium, boron or sulphur from the nutrient solutions are also described. Two forms of injury to the fruit observed in cultures deprived of boron are noted and illustrated.

Soil Sampling at Toddington

A large number of soil samples were taken in glasshouses on the site of the Glasshouse Crop Research Institute, and brought to Cheshunt for analysis.

Analytical Methods

Comparative potassium determinations by gravimetric methods and by the flame photometer have shown that the photometer gives reliable and consistent results for routine analysis, with a considerable saving in time.

PLANT PHYSIOLOGY

Dutch Light Temperatures

In collaboration with the Agricultural Branch, Meteorological Office, observations have continued on air and soil temperatures under dutch lights in comparison with those in an adjacent unprotected plot.

Root Growth Studies

Two glass-sided trenches were used for observations on the growth of the roots of one variety of tomatoes in a glasshouse border throughout the season. The effect on growth of stem and roots of removing all flower trusses from the row of plants on one side of the trench was determined in comparison with that of normal cropping on the other side.

Root Environment

Soil tensiometers were installed in a glasshouse border at different depths and distances from tomato plants and the trends of soil moisture tension were followed through the growing season. Comparisons were also made between a commercial type tensiometer and others assembled in the laboratory, installed in pots containing tomato plants. The Bourdon-gauge type was found to exhibit a considerable lag in response behind the laboratory type. The reason for this was examined.

An automatic, pressure-balance, recording tensiometer, used in a pot containing a tomato plant, has given encouraging results as an instrument for observing small soil tension changes during the wetting and drying cycles and rapid response to changes in the environment.

EXPERIMENTAL RESULTS OF 1953

I. TOMATOES

The practice of grading the tomato fruits from the experimental plots, adopted in 1921, was continued:—

- A. "Pinks" number 5 to 7 and "Pink and White" 8 to 10 to the lb. These are the best quality of fruit in size, shape and colour; "Pinks" being slightly larger than "Pink and Whites."
- B. "Whites." These fruits are of good colour but smaller than "Pink and Whites."
- C. "Blues." This grade consists of fruits of good colour but larger and more irregular in shape than Grade A.
- D. "Roughs." Small mis-shapen fruits about the size of cherries.
- E. Blotchy fruits which ripen irregularly.
- F. Fruits showing Blossom End Rot.
- G. Fruits showing the lesions of Streak Diseases.
- H. Fruits showing "Green Back."

(a) Chloropicrin v. Formaldehyde

In view of the unsatisfactory results in 1952 given by formaldehyde sterilization of the soil in comparison to steaming and injection with chloropicrin, the two chemical treatments were repeated in 1953, in house 3. Two plots were allocated to each treatment. The records are given in Table I and it will be seen that while there was little difference in total yields resulting from the different treatments, any difference was slightly in favour of formaldehyde.

(b) Planting Density

The experiments on planting density started in 1953, comparing crop yields from densities of 16,000 and 8,000 plants per acre. Although there was surprisingly little difference in total yield between the two densities, the greater number of plants per acre gave a return some £91 more than the lower density, owing to the slightly greater weight of fruit produced at the beginning of the season.

In 1953 a small experiment was carried out in two plots in house 3 in which the plants were planted at the usual density of 16,000 per acre. Half the plants, however, were stopped at the fifth truss, selecting them so that they were staggered in the double rows. After the five trusses of fruit had been picked, the stopped plants were removed entirely, but a sideshoot from the adjoining plant was trained up the empty string to fill the vacant space.

The results, shown in Table I, are almost too good to be true, because for each variety they show an increase of approximately 25 per cent. over the average of the two other plots.

The spacing experiments of 1952 and 1953 have proved so interesting that a comprehensive experiment is planned for 1954.

(c) Steam v. Chloropicrin

The experiments on soil sterilization involving the use of steam and chloropicrin were repeated in house 9 where four plots were steamed and four plots injected with chloropicrin. The results given in Table II show that both treatments gave approximately the same total yield of fruit, and furthermore there was no difference in earliness, the average yield from the steamed plots being 56.85 tons and the chloropicrin plots 56.93 tons per acre. This confirms previous results.

(d) Drip Watering

The drip-watering experiments were continued in house 5, but for the first time the addition of Krillium (Merloam) was made to half of both plots, and also to half the remaining plots in the house. The results are given in Table III. The average yield from the control plots watered in the usual way was 29.99 tons per acre. Where Krillium was mixed with the soil the yield was 31.39 tons per acre.

The plot receiving "drip watering" produced 32.07 tons per acre, but this fell to 29.72 where Krillium was applied.

The yields from this house and indeed those in houses 3 and 4 were all unusually low, but this was due to lack of labour over a period of 10 weeks caused by sickness. Owing to insufficient attention growth became congested and the crop suffered.

TABLE I
VARIETIES: POTENTIAL AND DOWNES SEEDLING

House	Plot	Variety	Planting Distance (Plants per Acre)	Treatment	Crop Yield in Lbs. per Square Yard					Tons per Acre	% Blotchy Ripening	
					May	June	July	Aug.	Sept.			Total
3	1	Potential	16,000	Soil injected with chloropicrin	0.17	50.4	4.61	4.71	4.21	18.74	41.23	0.57
	2	"	16,000	Soil sterilized with formaldehyde	0.07	4.63	5.16	4.50	4.75	19.11	42.04	0.37
	3	"	16,000 at first then half plants stopped at 5th truss and removed after cropping	As plot 1	0.06	5.58	6.96	5.11	6.76	24.47	53.83	0.85
6		Downes Seedling	16,000	As plot 1	0.45	5.79	3.95	3.58	2.59	16.36	36.00	0.48
	7	"	16,000	" "	0.42	5.95	2.96	4.32	3.08	17.73	39.00	3.36
	8	"	As plot 3	" "	0.34	5.76	5.24	5.13	4.84	21.31	46.88	1.04

TABLE II

House	Plot	Variety	Treatment	Crop Yield in Lbs. per Plant						Total Tons per Acre	% Blotchy Ripening	
				May	June	July	Aug.	Sept.	Oct.			Total
8	1	Hybrid 13	Steam	0-10	2-06	1-73	1-41	1-43	1-26	7-99	60-72	1-75
	8	" "	Chloropicrin	0-06	1-87	1-73	1-27	1-62	1-07	7-62	57-91	1-98
	2	" 14	" "	0-06	2-02	2-01	1-46	1-89	0-91	8-35	63-46	1-20
	7	" "	Steam	0-01	1-52	2-23	1-52	1-60	0-87	7-75	58-90	4-12
	3	" 15	Chloropicrin	0-02	1-88	1-69	1-13	1-91	0-95	7-58	57-61	1-32
	6	" "	Steam	—	1-47	1-97	1-26	1-46	0-95	7-10	53-96	2-67
	4	" 16	" "	—	1-98	1-72	1-17	1-42	0-79	7-08	53-81	6-78
	5	" "	Chloropicrin	—	1-56	1-94	1-13	1-14	0-64	6-41	48-72	9-21

TABLE III
VARIETY: E.S.5

House	Plot	Treatment	Crop Yield in Lbs. per Plant					Total Tons per Acre	% Blotchy Ripening	
			May	June	July	Aug.	Sept.			Total
5	1	Control watering	0.05	1.04	1.45	0.68	0.52	3.74	28.42	1.34
	2	"Merloam" added	0.02	0.91	1.72	0.61	0.89	4.25	32.30	0.47
	7	Drip watering	0.02	0.79	1.79	0.90	0.72	4.22	32.07	0.95
	8	"Merloam" added	0.02	0.97	1.61	0.77	0.54	3.91	29.72	1.02
	3	"Merloam" added	0.03	0.76	1.70	0.75	0.75	3.99	30.33	0.25
	6	"	0.01	1.05	1.34	1.04	0.71	4.15	31.54	—
	4	Control	0.03	1.16	1.53	0.92	0.76	4.40	33.44	0.46
	5	"	0.01	1.12	0.97	0.83	0.75	3.70	28.12	0.28

TABLE IV

House	Plot	Variety	Treatment	Crop Weight in Lbs. per Plant					Total Tons per Acre	% Blotchy Ripening	
				May	June	July	Aug.	Sept.			Total
4	1	Burgh Castle	C.A.—Nitrogen ...	0.05	1.17	0.30	0.45	0.32	2.29	17.40	1.31
	2	"	No manure	—	0.98	0.34	0.51	0.50	2.33	17.71	9.44
	3	"	C.A.	—	1.21	0.80	0.93	1.00	3.94	29.95	1.02
	14	"	" plus dung ...	—	1.11	0.94	1.01	0.77	3.83	29.11	1.31
	15	"	" minus phosphates	—	1.22	0.81	1.09	0.63	3.75	28.50	1.33
	16	"	" potash	0.01	1.14	0.90	0.73	0.53	3.31	25.16	1.63
	4a	Downes Seedling	" planted in 3-in. compost	0.04	1.32	0.75	0.69	1.18	3.98	30.25	—
	4b	"	"	0.01	1.70	0.95	0.90	1.28	4.84	36.78	—
	5	Marmand x L.M.R. 1; F2	"	0.02	1.69	0.60	0.66	1.29	4.26	37.38	0.47
	6	E.S.4 ...	"	0.01	1.38	1.25	0.78	0.91	4.33	32.91	3.00
	7	Tuckswold II; Guernsey	"	0.03	2.06	0.83	0.93	1.54	5.39	40.96	2.22
	8	Kondine Red	"	0.02	1.56	1.12	1.17	1.26	5.13	38.99	1.56
	9	Tuckswold improved x Potentate; F3	"	0.10	1.52	0.94	1.19	0.95	4.70	35.72	0.43
10	Tuckswold III; Pillmite	"	—	1.43	0.91	1.14	0.88	4.36	33.14	0.69	
11	St. Pierre x E.S.1; F3	"	—	1.25	1.32	1.27	1.20	5.04	38.31	2.18	
12	Fluffy smooth skin x Potentate F1	"	0.03	1.85	1.13	0.92	1.20	5.13	38.99	3.31	
13	Downes Seedling	"	0.03	1.31	0.99	1.10	0.68	4.11	31.24	0.24	

If any reliance can be placed on the results they indicate no difference in effect when drip watering is compared with the ordinary system. The effect of adding Krillium to the soil was also negative, so far as crop yield was concerned.

(e) Krillium (Merloam)

The experiments with the soil conditioner Krillium started in 1952, were repeated in houses 7 and 9 using the latest product "Merloam."

The material was mixed well with the soil in the recommended proportions prior to planting. As the soil was in a friable condition already no difficulty was encountered in the mixing process.

The effect on the soil was that already noted in 1952. Water applied to the surface ran through the soil more quickly and did not remain in puddles on the surface, but the soil retained moisture longer than that in the control plots.

Crop yield however was not affected. The average of nine plots receiving Krillium was 54.3 tons and that of the controls 55.12 tons per acre.

(f) The Omission of Lime and Phosphates

These experiments started in 1947 were continued. The results are given in Table VIII. It would appear that the withholding of lime and phosphates is at last producing an effect in the seventh year, for crop yields in the deficiency plots are all appreciably lower than in the control. Further the growth of the plants during the season was definitely strongest in the controls.

(g) Potentate and its Hybrids

For many years the variety Potentate has been widely grown in the glasshouse industry, despite its tendency to produce fruit of lower quality than many others. The fact that it ripens early and produces a heavy weight of fruit on the lower trusses makes it more profitable on many nurseries than the better quality varieties. All attempts to persuade growers generally to change over to one of the better varieties have failed for this reason.

It is clear, therefore, that the problem must be tackled in another way and that a variety must be found similar to Potentate in earliness and weight of crop production but providing greater freedom from coarseness and blotchy ripening.

As an introduction to this investigation many different strains of Potentate and related varieties from different parts of the world were grown in our experimental houses this year. Unfortunately none of them proved superior to our own strain of Potentate and many of them were much more susceptible to coarseness and blotchy ripening.

In addition some twenty F_1 hybrids having Potentate as one of the parents were grown. Some of these were very promising and will be examined further in 1954. The crop yields varied from 50 to 74 tons per acre. Hybrids chosen for future work were all heavy croppers remarkably free from blotchiness and yielding shapely fruit. It is possible, after testing the F_2 and F_3 generations that the F_1 generation may prove to have certain virtues not possessed by the others in which case the production of hybrid vigour F_1 seeds may have to be faced. The crop yields produced by the hybrids will be found in Tables IV-VII.

(h) Variety Trials

The tomato variety trials in the Rose House were continued. Results are given in Table IX.

The heaviest cropper Wilkinsons B. produced very large poor quality fruit and was undesirable. Unic and Export Wonder the next in order produced heavy yields of good shaped fruit, but lacked a little in quality.

2. CUCUMBERS

The cucumber experiments were continued in 1953, the results are given in Table X.

(a) "Drip Watering"

The drip-watering experiment in house D was continued, but this year there was no increase in crop production when compared with the bed watered in the usual way.

(b) Flat Beds v. Raised Beds

In house E there were two plots in which the manure and loam used for preparing raised beds were merely spread over the surface in the shape of a flat bed, twice the width and half the height

TABLE V

House	Plot	Variety	Treatment	Crop Yield in Lbs. per Plant						Total Tons per Acre	% Blotchy Fruit
				May	June	July	Aug.	Sept.	Oct.	Total	
7	1	Hybrid 9	Control	—	1.96	2.14	1.86	1.63	1.44	9.03	68.63
	9	"	Merloam added	—	1.65	1.53	1.30	1.43	1.03	6.94	52.74
	2	Hybrid 10	Control	0.07	1.81	1.96	2.52	1.78	1.26	9.40	71.44
	8	"	Merloam added	—	2.15	1.73	1.67	1.67	1.23	8.45	64.22
	3	Hybrid 11	Merloam added	0.10	2.30	2.01	1.80	2.02	1.38	9.61	73.03
	7	"	Control	—	2.03	1.51	1.44	1.52	1.29	7.79	59.20
6	4	Hybrid 12	"	0.24	2.04	2.17	1.82	1.92	1.57	9.76	74.18
	5	E.S.5	"	0.01	0.90	1.76	1.05	1.14	0.58	5.44	41.35
	5	"	"	—	1.67	1.73	1.13	1.64	1.14	7.31	55.56
	6	Hybrid 4	"	—	—	—	—	—	—	—	—

TABLE VI

House	Plot	Variety	Treatment	Crop Yield in Lbs. per Plant						Total Tons per Acre	% Blotchy Ripening	
				May	June	July	Aug.	Sept.	Oct.			Total
9	1	Hybrid 17	Merloam added	0.06	1.62	1.65	1.26	1.02	1.62	7.23	54.95	13.01
	16	"	Control	—	1.35	1.78	1.21	1.34	1.32	7.00	53.20	12.58
	2	Hybrid 18	Merloam added	—	1.29	1.61	0.89	0.96	0.99	5.74	43.62	18.12
	15	"	Control	—	0.97	1.79	1.14	1.43	1.30	6.63	50.39	19.15
	3	Hybrid 19	"	—	1.01	2.35	1.22	1.13	1.47	7.18	54.59	15.32
	14	"	Merloam added	—	0.80	2.49	1.29	1.38	1.39	7.35	55.86	16.46
	4	Potentate (N.2)	Control	—	0.63	2.68	1.30	1.45	1.54	7.60	57.76	21.44
	13	" (E. & R.S.)	Merloam added	—	0.42	2.79	1.62	1.35	1.34	7.52	57.15	21.54
	5	" (Danish)	"	—	0.63	2.55	1.13	1.27	1.60	7.18	54.57	16.71
	12	" (E. & R.S.)	Control	—	0.26	2.74	1.68	1.27	1.21	7.16	54.42	19.97
	6	"	Merloam added	—	0.51	3.03	1.48	1.19	1.57	7.78	59.13	18.77
	11	"	Control	—	0.26	2.74	1.68	1.27	1.21	7.16	54.42	19.97
	7	Potential	"	—	0.22	1.51	1.01	1.07	1.67	5.48	41.65	6.57
	8	"	"	—	0.17	2.30	0.88	1.01	1.24	5.60	42.56	6.79
	9	"	Merloam added	—	0.02	1.73	1.10	0.98	1.37	5.20	39.52	4.23
	10	"	"	—	0.07	1.90	1.27	1.22	1.67	6.13	45.59	6.85

TABLE VII

House	Plot	Variety	Crop Yield in Lbs. per Plant						Total Tons per Acre	% Blotchy Ripening
			May	June	July	Aug.	Sept.	Oct.		
10	1	Duffern's Seedling	—	0.91	1.92	1.50	1.91	1.18	7.42	0.68
	2	Virum B	—	0.06	1.03	0.84	0.81	1.20	3.94	1.52
	3	Wheatley's W.W.	—	0.14	1.43	1.22	0.93	1.38	29.94	3.53
	4	L.M.R., No. 1	—	0.14	1.73	0.70	1.22	1.67	38.76	3.66
	5	Potentate (E. & R.S.)	—	0.25	2.52	1.74	1.17	1.47	41.50	14.93
	6	Hybrid 20	—	0.61	2.43	1.93	1.66	1.80	54.49	17.44
	7	" 21	—	0.59	2.20	1.92	1.32	1.69	64.07	16.84
	8	" 22	—	0.43	2.01	2.01	1.86	1.68	58.67	13.77
	10	" 25	—	0.23	2.12	2.60	1.77	2.04	62.72	13.70
	11	Delicious	—	0.09	1.90	2.12	1.86	1.57	66.58	4.77
	12	Downe's Seedling	—	0.23	2.18	1.51	1.80	1.87	57.68	5.27
	13	Buckley	—	0.17	1.77	1.31	1.15	1.92	48.03	5.06
	14	Hillside Comet	—	0.37	1.04	1.23	0.87	1.53	38.30	7.74
	15	Hybrid 26	—	0.79	2.32	1.87	1.56	1.73	62.85	5.07
	16	" 24	0.02	1.03	1.68	1.68	1.54	1.41	55.94	20.51

TABLE VIII

House	Plot	Variety	Treatment	Crop Yield in Lbs. per Plant						Total Tons per Acre	% Blotchy Ripening
				May	June	July	Aug.	Sept.	Oct.		
11	1	E.S.1	Control	—	1.38	1.94	1.93	1.70	0.95	60.04	0.64
	2	Ailsa Craig	"	0.02	1.40	1.83	1.98	1.53	0.71	56.77	0.40
	3	E.S.1	Lime omitted	—	1.13	1.83	1.98	1.37	0.69	49.83	0.57
12	4	Ailsa Craig	"	—	0.95	1.77	1.65	1.11	0.63	46.44	0.99
	1	E.S.1	Phosphates omitted	0.10	1.56	1.41	1.50	1.47	—	45.90	0.33
	2	Ailsa Craig	"	0.05	1.60	1.69	1.81	1.99	—	54.26	0.28
	3	E.S.1	Lime and Phosphates omitted	0.04	1.42	1.59	1.78	2.05	—	52.29	0.74
	4	Ailsa Craig	Lime and Phosphates omitted	0.06	1.49	1.54	1.68	1.88	—	50.54	0.91

TABLE IX

House	Plot	Variety	Crop Yield in Lbs. per Plant							Total Tons per Acre	% Blotchy Ripening
			May	June	July	Aug.	Sept.	Oct.	Total		
Rose	1	Unic	0.16	2.41	1.70	1.28	1.81	0.63	7.99	60.72	3.26
	2	Export Wonder	0.20	2.24	1.96	1.69	1.69	0.30	8.08	61.41	4.08
	3	Gouden Star	0.05	2.01	1.83	1.41	1.50	0.42	7.22	54.87	1.80
	4	E.S.5	0.06	2.22	2.52	1.17	1.32	0.09	7.38	56.09	2.03
	5	Antimold A	0.02	2.11	2.23	0.91	1.13	0.09	6.49	49.32	13.25
	6	Antimold B	—	1.18	2.43	1.10	1.11	0.07	5.89	44.76	1.53
	7	Wilkinson A	—	1.73	2.26	0.92	1.20	0.22	6.33	48.11	24.65
	8	B	—	2.09	2.23	1.61	1.72	0.74	8.39	63.76	10.24
	9	L.M.R. No. 1 (1936 seeds)	—	0.98	1.96	1.71	1.93	0.49	7.07	53.73	0.71
	10	E.S.5	—	1.61	1.84	1.39	1.77	0.67	7.28	55.33	0.69

TABLE X
CUCUMBER EXPERIMENTS. VARIETY: BUTCHER'S DISEASE RESISTER

House	Plot	Treatment	Crop Yield in Lbs. per Plant							Total Tons per Acre	Total Flats per Foot	
			Mar.	Apr.	May	June	July	Aug.	Sept.			Total
D	2	Control ...	0.10	12.98	10.12	9.97	7.40	8.50	5.09	54.16	81.24	1.69
	3	Drip watering ...	0.04	12.86	9.51	10.70	7.01	9.46	4.22	53.80	80.70	1.68
	4	Brick trough ...	0.13	10.97	6.58	9.05	6.64	5.62	0.48	39.47	59.20	1.23
	5	No lime ...	0.18	12.93	9.77	10.85	8.11	6.57	4.43	52.84	79.26	1.65
	1	Manure dug into border. No prepared bed. Planted direct in border ...	0.07	11.02	7.53	8.87	6.26	4.63	2.17	40.55	60.82	1.27
E	2	Flat beds ...	—	11.30	8.02	8.85	6.62	5.58	2.80	43.17	64.75	1.35
	3	Control ...	0.16	11.06	8.29	8.42	7.16	5.55	3.71	44.35	66.52	1.39
	4	Flat beds ...	—	10.47	8.55	8.14	7.63	6.14	3.85	44.78	67.17	1.40
	5	Control ...	0.12	11.41	8.28	8.66	7.30	4.89	2.36	43.03	64.54	1.35
	6	" ...	0.37	11.45	7.87	8.82	7.93	6.91	2.84	46.19	69.28	1.45
	1	Stable manure dug into shallow trench below plants. No prepared border ...	0.07	10.12	7.62	9.21	5.60	4.77	1.92	39.31	58.96	1.23
F	2	Control ...	0.17	9.27	7.34	9.82	7.38	4.73	2.84	41.55	62.32	1.30
	3	Sulphur, no Lime ...	0.32	9.19	6.64	8.21	7.07	4.53	3.05	39.01	58.51	1.22
	4	Two parts Lime ...	—	11.03	8.01	10.10	7.69	7.21	4.25	48.29	72.43	1.51
	5	Control ...	—	12.16	8.07	9.50	9.62	7.20	5.22	51.77	77.65	1.62
	6	Two parts Lime ...	0.16	11.51	7.72	8.11	7.95	5.26	3.57	44.28	66.42	1.39
	7	Sulphur, no lime ...	0.32	11.02	6.15	8.45	6.64	3.83	1.59	38.00	57.00	1.19
	8	Control ...	0.76	11.03	7.68	8.56	7.74	4.54	3.22	43.53	65.29	1.36

of the usual beds. There were also three normal raised beds to act as controls. Apart from the fact that the raised beds were a little earlier than the others, there was no difference in total crop. The average yield from the flat beds was 65.96 tons and the control beds 66.78 tons per acre.

Also in house E, was one bed in which horse manure was merely dug into the border, without attempting to bring in any new loam. Young cucumber plants were planted directly, into the border. The yield in this case was rather less than the control, being 60.82 tons per acre. In house F stable manure was placed in a shallow trench beneath the young plants. Here again the yield was reduced (58.96 tons per acre).

(c) Lime and Sulphur

The importance of lime in cucumber beds was shown in house F.

Three control plots produced an average yield of 68.42 tons per acre. Where the amount of lime incorporated with the soil was doubled the average yield remained almost the same, i.e. 69.43 tons per acre. Where lime was withheld and 2 ozs. flowers of sulphur added to every 100 lbs. of soil instead, then the average yield fell to 57.91 tons per acre.

II. PLANT DISEASES

I. DIDYMELLA STEM ROT

By P. H. WILLIAMS and JUDITH HACK

Experiment in House 1

Previous work³ has shown that addition of straw or, to a less extent, stable manure to soil leads to increased growth of *Didymella lycopersici*. It has also been claimed² that digging in stable manure leads to more severe attacks of Stem Rot. An experiment was therefore carried out in House 1 to test the effect of stable manure both in steamed and unsteamed soil. Since it has also been found that *D. lycopersici* does not readily establish itself in unsteamed soil,³ possibly as a result of competition from the existing soil microflora, an attempt was made to protect sterilized soil by inoculating it with organisms from unsterilized soil.

Thirty-two plots were laid out each to contain 20 plants and treatments applied as follows:—

- (1) Steamed, inoculated with *D. lycopersici*.
- (2) Steamed, 30 tons stable manure per acre before steaming, inoculated.
- (3) Steamed, 30 tons stable manure per acre after steaming, inoculated.
- (4) Unsteamed, inoculated.
- (5) Unsteamed, 30 tons stable manure per acre, inoculated.
- (6) Steamed, inoculated with soil organisms and *D. lycopersici*.
- (7) Steamed, inoculated with soil organisms only.
- (8) Steamed, uninoculated control.

Each treatment was replicated four times and the plots were randomised within four blocks. For convenience in steaming it was necessary to change the position of some plots so as to bring plots 4 and 5 together in each block.

The soil was steamed by the Hoddesdon pipe method on December 3rd, 1952. The plots were then delimited by means of strips of asbestos sheet in order to minimise spread of the fungus from plot to plot when watering. The soil was limed and flooded two weeks after steaming. The soil organisms were applied after flooding. Soil from House 1 was removed before steaming and stored until required. It was then shaken up in water and filtered through filter paper. Preliminary experiments had shown that filtration removed fungi to a much greater extent than bacteria and it was hoped by this means to lessen the chances of re-infection by pathogenic fungi such as *Phytophthora parasitica* and *Verticillium albo-atrum*.

The soil was inoculated with *D. lycopersici* on January 2nd and 3rd, 1953, by watering with a spore suspension. Approximately 235 million spores were applied to each plot.

Addition of base manures and all other cultural operations conformed to normal practice, precautions being taken to prevent infection being carried from one plot to another. Diseased plants were removed as soon as they were seen. Planting with the variety Potentate was done on March 10th and 11th and the plants were finally cut out on November 4th.

The first basal lesion was found on April 7th, but the disease did not make rapid progress until the beginning of May. Between then and the end of June a number of diseased plants were found but after that the progress of the disease slackened although basal lesions occurred right up to the end of the experiment. Despite care in watering, lesions also occurred at varying distances up the stem, the first being found on July 1st.

The addition of stable manure did not significantly affect the amount of disease on steamed soil. Where the manure was dug in before steaming, the number of diseased plants was slightly less than on the plots without manure and where the manure was added after steaming. It might be expected that *D. lycopersici* would grow more freely on the sterilized manure but possibly growth by contaminating fungi between steaming and inoculation was sufficient to prevent its doing so. Infection on the unsteamed plots was slight, thus confirming previous observations. The addition of soil organisms did not prevent *D. lycopersici* from causing as much disease as on the other steamed plots.

Only 14 infected fruit were picked during the season. They accounted for about 2 lbs. out of a total of 4,432 lbs., a negligible proportion.

Losses of crop were due to both basal and stem lesions caused by *D. lycopersici* and to plants killed by *Botrytis cinerea* and *Verticillium albo-atrum*, the latter occurring only on unsteamed plots. These fungi, however, only accounted for 13 plants against 223 killed by *D. lycopersici*, so that their effect

was small. The control plots gave an average crop equivalent to 63.61 tons per acre, that on the other steamed and inoculated plots varying between 70 and 83 per cent. of this figure. The unsteamed plots were little affected by the disease and gave crops of 50.62 tons per acre on the unmanured and 52.36 tons per acre on the manured.

The loss of crop depends upon two factors, the number of plants killed and the time at which they become diseased. The sum of the reciprocals of the times between planting and removal of infected plants gives a "disease index" which integrates these two factors. The regression coefficient between the crop of each steamed plot and its "disease index" was calculated and found to be highly significant. The losses can therefore be ascribed to the disease and not to cultural causes. Only one plot (1A) was found to be notably lower than could be accounted for by disease only. This plot at the cooler end of the house came into bearing later than the remainder and also had the severest losses from disease, 80 per cent. of the plants being killed by the end of the season.

Survival of *D. Lycopersici* in Soil

At the end of the 1952 growing season, the plants were carefully removed from the pots which had been used for an experiment in House 1¹ and the pots taken from the glasshouse and stored out of doors. Each was covered with a circular glass plate to prevent soil being splashed from one pot to another by rain. In June 1953 tomatoes variety Potentate were planted in them, the soil being disturbed as little as possible. The plants were kept out of doors near the laboratory.

The first infected plants were found on August 25th and by the middle of October six plants had shown lesions at soil level and seven plants lesions higher up the stem. The latter were mainly in one group and probably the fungus was spread by splashing during watering or by rain. In 1952, 60 out of the 80 pots had contained diseased plants and therefore if losses by basal lesions only are counted, it would appear that the fungus survived in 10 per cent.

In 1952, a small experiment was carried out in which broken up tomato stems infected with *D. lycopersici* were buried at various depths in soil in 10-in. pots. Tomatoes were then planted in the pots and two out of 10 became infected. The pots were kept in the glasshouse after removal of the plants and replanted in the spring of 1953. One plant contracted Stem Rot.

It has been shown previously that cultures of the fungus can survive in pots of soil stored in the laboratory for 44 weeks³. The experiments described above show that it can survive in pots either in the open or under glass from one season to the next either as mycelium in the soil or on dead roots. Certain plots, which showed severe Stem Rot in the 1953 experiment in House 1, have been left untreated except for normal cultivations and should provide evidence on the survival of the fungus in glasshouse borders.

Growth of *D. Lycopersici* in Different Soils

Several cases have been noted in which one of two contiguous nurseries has remained free of *Didymella* Stem Rot while the other has always suffered to some extent from the disease.

Six samples of soil were obtained from three such pairs of nurseries and the ability of two strains of *D. lycopersici* to grow on them in pure culture determined. On one pair of soils, both strains grew more freely on soil from the nursery on which Stem Rot occurred. On another pair, one strain of the fungus behaved in the same way but the other strain did the reverse. On the third pair of soils, both strains grew very poorly and both grew best on soil from the nursery on which Stem Rot did not occur. No relationship could be seen between the growth of the fungi and the organic carbon and nitrogen contents, acidity, total salt content or microbial activity as measured by the evolution of carbon dioxide. The measurements of these soil properties were kindly made by the Chemistry Department.

The causes which determine whether Stem Rot will occur on a nursery are evidently very complex. From the fact that both strains of *D. lycopersici* grew well on two pairs of soils and poorly on the third, it would appear that soil type may have some influence. Biological factors may also enter into it, but the results previously reported¹ suggest that in all soils there are many organisms which can produce substances antibiotic to *D. lycopersici*.

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2. TOMATO ROOT STUDIES

By P. H. WILLIAMS and M. H. EBBEN

The Effect of Fallowing and Steaming on the Tomato Rhizosphere

The plots used in this investigation had been used during 1952 for steam sterilization studies. A section of the tomato border was steamed in the autumn of 1951 and divided into three plots in 1952, one of which was base dressed and planted with tomatoes, a second base dressed and left fallow, and the third fallowed without the addition of any fertilizer.

A second length of border had been similarly divided and treated but left unsteamed. In the autumn of 1952 these three previously unsteamed plots were steamed while the others were left untreated. Another plot which had been planted with tomatoes for four successive years without being steam sterilized was also used for comparison. These seven plots were numbered as follows:—

1952 Treatment				Unsteamed	Steamed, Autumn 1952
3	Fallowed unfertilized	...	...	1	4
1	Planted	...	...	2	5
2	Fallowed fertilized	...	...	3	6
4	Unsteamed four years	...	...	7	

All plots were treated similarly in 1953 being flooded, base dressed and planted out with tomato plants in March.

Isolations of micro-organisms were made at appropriate dilutions on Waksman's agar containing 1 : 15,000 rose bengal for fungi, and on yeast extract tryptone agar as used by Taylor¹ for bacteria. Samples for estimating soil organisms were taken at a depth of 3–6 ins. as root and outer rhizosphere samples were also taken from this level. The outer rhizosphere and root surface populations were isolated as reported previously,² but the numbers of organisms on the root surface have been expressed as numbers per gramme of fresh root weight, instead of per square centimetre of root surface. Root infection was estimated by plating sections of the roots which had been used for making the root surface dilutions on agar plates after surface sterilization with calcium hypochlorite. Rhizosphere counts were made separately on three root systems from the same plot. Although the range in numbers of micro-organisms on these individual roots was often wide the differences were not found to be significant.

Soil counts were started on unsteamed plots in December, 1952, and on the steamed plots at the beginning of January, 38 days after steaming. Samplings were repeated at approximately monthly intervals until May, and further soil counts were made in July and October when rhizosphere estimations were made. The soil samples taken in July and October were really within the rhizosphere region, since by July all the soil between the rows of plants were permeated with fine rootlets and although by October most of these fine roots had disappeared the decay of the roots might be expected to influence the microbial activity.

The numbers of bacteria in the soil were greatly reduced by steaming and only a slight increase occurred during January. In the samples taken 23 days after flooding, however, a large increase in numbers was apparent, an increase which also occurred, although on a smaller scale, in all the unsteamed plots. After flooding, the numbers of bacteria in the steamed plots actually rose to a higher level than in the unsteamed soils, but this was followed by a gradual decrease. Of the unsteamed plots 1 and 7 gave the higher counts, and the increase in numbers which occurred after flooding was continued after the plants had been put out. In the steamed plots the increase in numbers after planting was not so marked, and the bacterial population did not increase much above the high level reached after flooding. For the greater part of the growing season it appeared that there were no significant differences in bacterial numbers between the steamed and unsteamed series. Samples taken in July and October gave progressively lower counts of bacteria in all plots.

The numbers of bacteria in the outer rhizosphere soil of plants examined in July and October showed no significant variations between plots or between the two sampling dates. There was a tendency for the plants from steamed plots to give slightly higher counts which was probably a reflection of the higher soil numbers in these soils. Counts of root surface bacteria gave some anomalous results. No significant differences between plots was found in July, but in October Plot 1 gave a very high count, while numbers from Plot 2 were very low, plants from the other unsteamed plot also showed a considerable drop from the July numbers, but in the steamed series there was far less variation. Fallowing treatment in the steamed and unsteamed series did not produce any differences in the root surface bacterial numbers.

Soil fungi like bacteria showed a large decrease in numbers in the steamed plots. Steaming

appeared to reduce the fungi which could be isolated by plating to almost nil. The first samples were taken about 40 days after steaming and numbers then were still very low. There was a gradual increase throughout February, March and April and samples taken in July when the soil was full of rootlets gave the highest counts. In October numbers were again lower and no significant increase seemed to have occurred in soil fungal numbers after April. Fallowing did not give rise to any differences in fungal numbers in the steamed plots. Similarly in the unsteamed series fallowing did not produce any marked differences between plots, but Plot 7 which had not been steamed for four seasons gave much higher soil counts of fungi than any of the plots left unsteamed for one year. In this series of plots there was an increase in numbers between April and May, but counts in July and October fell considerably.

Numbers of fungi from the outer rhizosphere were lower from plants in the steamed plots in July, but neither the steamed nor the unsteamed series showed differences between fallowing treatments. Plot 7 did not give higher outer rhizosphere counts than the other unsteamed plots, although the numbers of soil fungi were higher.

By October no differences between outer rhizosphere soil counts were noted in either the steamed or unsteamed series. Two plots in the unsteamed series, Plots 1 and 2 showed a significant fall in the numbers of fungi isolated between July and October and this coincided with a large drop in the numbers of soil fungi. In other plots there were smaller changes in soil numbers between July and October and changes in rhizosphere numbers did not seem to be related to numbers in the soil. This together with the lack of effect which the high soil numbers in Plot 7 appeared to have on the rhizosphere suggests that there is not necessarily a direct relation between numbers of soil fungi and the numbers in the outer rhizosphere soil.

When counts of fungi were made from the root surface there were very wide variations between numbers isolated from the roots of plants in the same plot, and no significant differences were noted between the plots or between samples taken in July and October.

Bacterial infection of roots examined in July and October varied only slightly from plot to plot, even when comparing roots from steamed and unsteamed soil. The percentage infection with fungi did show marked differences both from plot to plot and at different sampling dates. There was a significant rise in the infection of roots from the three unsteamed plots from July to October, numbers in the fallowed at both times being only slightly lower. In the steamed plots roots from Plot 4 showed a rise in fungal infection in October, but the other two plots and Plot 7 gave approximately the same amounts of infection both in July and October. The percentage fungal infection of the roots examined from Plot 7 tended to be lower than that found in roots from Plot 2, which had only carried two crops since being steamed, especially in October. This was probably due to the growth of new adventitious roots from the stem base and tap root of plants in Plot 7, where in other plots the decay of the feeding roots had not occurred so rapidly and new roots had not been produced by the end of the season. As with the unsteamed series, fallowing made no appreciable difference to the fungal infection of the roots from the steamed plots. Infection in the steamed plots was always lower than in the comparable unsteamed plot, this decrease being greatest between the unfallowed plots.

The different fungal species isolated from the soil and rhizosphere on dilution plates were counted and populations from different sources compared. The more common species isolated were expressed as a percentage of the total population and listed as follows: rare 0-5, occasional 5-15, frequent 15-30, abundant 30-50, dominant 50-100 per cent.

The soil fungi isolated from plots at the end of 1952 until May, 1953, that is from steaming onwards, were markedly different in the steamed and unsteamed soils. Far fewer species were found in the steamed plots and Phycomycetous fungi were more common. The fungus numbered 54 occurred most often in Plot 7 and was dominant in the soil of this plot from February until October, it was frequent and sometimes abundant to dominant in Plots 1 and 2, but was less common in the fallowed and fertilized Plot 3. In the corresponding steamed plots it was less common and was not isolated from Plot 6. Species of *Penicillium* were frequent and sometimes abundant in all soils but there was a tendency for greater numbers to occur in the steamed plots. *Myrothecium roridum* which was occasional to frequent in all the unsteamed soils was only isolated rarely from steamed plots and then not until the middle of the season. *Chaetomium cochliodes*, which occurred only rarely in the unsteamed soils, was absent altogether from the steamed and fallowed Plots 4 and 6. *Trichoderma viride* was isolated sporadically from all plots.

In the outer rhizosphere as in the soil the fungus 54 was again abundant in the unsteamed plots and less frequent from the rhizospheres of plants in steamed soil. Numbers of *Penicillium* spp. from the outer rhizosphere soil paralleled those from soil being larger in the steamed plots., *M. roridum* occurred only rarely in most plots and was not isolated at all from Plots 5 and 6.

C. cochliodes, which was rare to occasional in the rhizosphere of plants in the steamed plots in July and October, was only isolated from the unsteamed plots in July. *T. viride* and *Mucor* spp. were rare from the outer rhizospheres in all plots. *Volutella ciliata* and *Fusarium* spp., which were only rarely isolated from soils, were more common in the rhizosphere soils. *V. ciliata* tended to occur more often in the middle than at the end of the season.

Isolations from the root surface showed obvious differences from those from the rhizosphere soils. *Colletotrichum atramentarium* was present on roots from all unsteamed plots. In Plots 1, 2 and 3 this fungus increased from being occasional to frequent in July to being dominant on roots in October. In Plot 7 it was already the dominant fungus isolated from the root surface in July, but showed a decrease in October, probably due to the growth of new adventitious roots from the scarred tap root. In the steamed and fallowed Plots 4 and 6 *C. atramentarium* was not isolated from the root surface in July and occurred only occasionally in October. In Plot 5 which had been cropped the previous season it was rare both in July and October. The fungus 54 also occurred in the root surface flora, and was again more common in unsteamed plots. It appeared to decrease in importance in October in all plots. Species of *Penicillium* were again more frequent on roots from steamed soils. *Thielaviopsis basicola* was isolated from the root surface of plants in most plots but was usually rare. *V. ciliata* tended to occur more frequently on roots earlier in the season. *Fusarium* spp. were frequent to abundant especially on steamed plots where *C. atramentarium* was less frequent, and were isolated most regularly from fallowed plots. Other species which occurred rarely on the root surface were *M. roridum*, *T. viride*, *Mucor* spp. and *Chaetomium* spp.

A comparison of the fungi isolated from the internal tissues of the roots showed distinct differences between roots from steamed and unsteamed soils. *C. atramentarium* was dominant in roots from all the unsteamed plots in October and in July was dominant in Plots 3 and 7. It was not isolated from roots in Plot 1 in July, although it was recorded as occasional on the root surface of these plants at this time. In the steamed plots *Fusarium* spp. and *V. ciliata* were the most commonly isolated fungi. *C. atramentarium* although rare or absent from roots in July was frequently isolated in October. *Mucor* spp., *T. viride*, *Botrytis cinerea*, *M. roridum* and *T. basicola*, which were recorded from the root surface, were not isolated from root tissues. *Chaetomium* spp. were isolated sporadically from roots in all plots and tended to occur more often in the earlier part of the season.

It appears that the numbers of bacteria and fungi isolated from glasshouse soils by the dilution plate method were not appreciably affected by fallowing although steaming did lead to significant changes. Differences in the species isolated show that steaming causes a big drop in the occurrence of *C. atramentarium* on the root surface and in the root tissues. Fallowing also produced a slight decrease in the occurrence of this fungus in the earlier part of the season, but by October it was as widespread as in the continuously planted plots.

REFERENCES

¹ TAYLOR, C. B., Proc. Soc. Applied Bact., 1951, 14, 101.

² WILLIAMS, P. H., and EBBEN, M. H., Rep. Exp. Res. Sta., Cheshunt, 1951, 22.

3. VIRUS DISEASES

By R. HOWLES

Therapy

Heat Treatment

Tomato seeds taken from plants heavily infected with virus were again heated at 142.5° F. for 22 days. At the three-truss stage for two experiments carried out in 1953 the number of infected plants was two out of 200 in case of plants from treated seed and from untreated seed. The heat treatment which had destroyed most of the virus in the seed had resulted in plants more susceptible to virus infection.

Work carried out last year had indicated that the best treatment for curing Arum Lily corms infected with spotted wilt virus was a treatment in normal atmosphere at 107.5° F. for 66 days. Thirty corms were given this treatment: there were 30 controls. The number of corms which grew was: from treated corms, 22; from controls, 25. There were 11 infected plants from the treated corms and 13 from the controls. There was no practical value in the treatment.

Effect of Heat Treatment on Seedling Weight

It was shown here last year that seedling weight in the case of heat-treated virus-infected seed was greater than that of heat-treated virus-free seed. This effect on seedling weight was due to the



Fig. 1. Effect of treatment at 150° F. on seedling weight of clean and infected seed.

virus which must be inside the seed. Further data showing the same effect are given in Table I and illustrated in Fig. 1.

TABLE I
EFFECT OF HEAT-TREATING TOMATO SEED IN NORMAL ATMOSPHERE ON THE ABILITY OF THE SEED
TO GERMINATE AND ON SEEDLING WEIGHT

	Treatment		Number of Seeds germinated out of 45, 17 days after Sowing	Average Weight of Seedling
	Temperature ° F.	Duration H		
Clean seed ...	150	1	40	0.078 gm.
	150	2	42	0.073 gm.
	150	3	27	0.056 gm.
	—	—	41	0.066 gm.
	150	4	37	0.058 gm.
	150	5	38	0.057 gm.
	150	6	41	0.063 gm.
	—	—	43	0.063 gm.
	150	1	32	0.069 gm.
	150	2	29	0.053 gm.
	150	3	15	0.040 gm.
	—	—	37	0.060 gm.
	150	4	20	0.055 gm.
	150	5	21	0.046 gm.
	150	6	30	0.053 gm.
	—	—	40	0.064 gm.
	150	1	37	0.093 gm.
	150	2	27	0.076 gm.
	150	3	27	0.065 gm.
	—	—	40	0.081 gm.
	150	4	32	0.071 gm.
	150	5	34	0.066 gm.
	150	6	30	0.074 gm.
	—	—	29	0.073 gm.
Infected seed ...	150	1	34	0.066 gm.
	150	2	30	0.068 gm.
	150	3	30	0.067 gm.
	—	—	33	0.062 gm.
	150	4	38	0.056 gm.
	150	5	32	0.076 gm.
	150	6	25	0.062 gm.
	—	—	41	0.067 gm.
	150	1	28	0.057 gm.
	150	2	24	0.060 gm.
	150	3	29	0.064 gm.
	—	—	23	0.054 gm.
	150	4	14	0.058 gm.
	150	5	18	0.054 gm.
	150	6	19	0.054 gm.
	—	—	26	0.053 gm.
	150	1	31	0.069 gm.
	150	2	27	0.053 gm.
	150	3	30	0.071 gm.
	—	—	34	0.061 gm.
	150	4	32	0.062 gm.
	150	5	29	0.065 gm.
	150	6	24	0.068 gm.
	—	—	28	0.064 gm.

Chemical Treatment

In our 1952 Annual Report it is reported that 2, 4-dichlorophenoxy-acetic acid has some therapeutic action. Hence it was decided to try other related chemical substances. Groups of young potted chrysanthemum cuttings infected with flower distorting virus, 20 plants per group, were taken. 100 ml. of a solution of one of the related chemicals was applied to the soil in each of the pots of one of the groups. Using a different chlorophenoxy-acetic acid compound this was repeated in the case of each of the other groups. The plants were tested for virus one month after treatment.

Table II lists the chemicals used and the effect of each on the plant itself and virus content.

2-chlorophenoxy-acetic acid was the best chemical; there was no effect on the plant itself and the plant was freed from virus.

TABLE II
EFFECT OF VARIOUS CHLOROPHENOXY-ACETIC ACID COMPOUNDS ON CHRYSANTHEMUM PLANTS
AND FLOWER-DISTORTING VIRUS IN THEM

Chemical	Concentration	Effect on Plant itself	Number of Infected Groups* out of 4	
			Tested after 1 Month	Tested after 2 Months
2-Chlorophenoxy-acetic acid ...	0.013%	None	0	1
3-Chlorophenoxy-acetic acid ...	0.013%	None	0	2
4-Chlorophenoxy-acetic acid ...	Half saturated	Slight distortion	0	-
2, 5-Dichlorophenoxy-acetic acid	0.013%	None	1	-
2, 6-Dichlorophenoxy-acetic acid	0.013%	Some distortion of foliage, yellowing of same	1	-
2, 4, 5-Trichlorophenoxy-acetic acid	Half saturated	None	3	-
2, 4, 6-Trichlorophenoxy-acetic acid	Half saturated	None	2	-
2, 4-Dichlorophenoxyacetanide	Half saturated	None	3	-
2, 4-Dichlorophenoxyacetic acid, ammonium salt	0.013%	Harmed somewhat	0	-
2, 4-Dichlorophenoxyacetic acid, diethylamine salt	0.013%	Harmed somewhat	2	-

* Groups consist of five plants each.

Attempts were made to find if chemical treatment of the soil would prevent plants from becoming virus infected. Tomato plants were used in the work. In an experiment there were three groups of plants, 20 per group. One group acted as the controls. The soil of each of the other groups was treated with a chemical solution reported as having therapeutic action. The soil in each pot was given 100 ml. on each of five days immediately preceding treatment with virus. The plants, at the six foliage leaf stage, were treated with aucuba mosaic virus (spring, summer) or potato virus X (autumn). There were 200 ml. of virus solution per gm. of infected leaf and no carborundum was used. The plants were finally examined for symptoms four to five weeks after treatment with virus. The chemicals used and the effect on the plants and in delaying or accelerating the appearance of symptoms of virus infection are contained in Table III.

TABLE III
EFFECT OF CHEMICAL TREATMENT OF TOMATO PLANTS PRECEDING INOCULATION WITH VIRUS
ON TIME OF APPEARANCE OF SYMPTOMS OF INFECTION

Chemical Solution	Effect on the Plant	Virus applied to Plants	Date	No. of Plants showing Symptoms of Infection	
				Treated Plants	Control Plants
0.025% malachite green ...	Not harmed.	Aucuba mosaic virus.	17/4/53 9/5/53 22/5/53	4 out of 20 12 " " 20	5 out of 15 10 " " 15
0.025% zinc sulphate ...	Not harmed.	Same virus.	17/4/53 9/5/53 22/5/53	9 out of 20 18 " " 20	5 out of 15 10 " " 15
0.025% 8-hydroxyquinoline- sulphate	Not harmed.	Same virus.	22/7/53 17/8/53	16 out of 20	19 out of 20
0.0125% hydroquinone ...	Not harmed.	Same virus.	22/7/53 17/8/53	17 out of 20	19 out of 20
Saturated thiazamide ...	Not harmed.	Potato virus X.	21/9/53 12/10/53 19/10/53	8 out of 20 13 " " 20	13 out of 20 15 " " 20
Saturated 2-chloro- phenoxy-acetic acid ...	Later distorted somewhat.	Potato virus X.	21/9/53 12/10/53 19/10/53	8 out of 20 9 " " 20	13 out of 20 15 " " 20
Applied once.					

Malachite green, considered to be a promising therapeutant, delayed the appearance of symptoms, but resulted in no control. Zinc sulphate accelerated the appearance of symptoms. Of the other chemicals 2-chlorophenoxy-acetic acid produced some control but the rest had no therapeutic value.

Other Treatments

TREATMENT WITH SHORT-WAVE RADIATION

Tomato (Potential) and lettuce (Cheshunt 5B) seed both virus infected (the former harvested in 1952) were subjected to short-wave radiation, the dose being three times the intensity of that given to seed last year. Treated seed and the control seed were sown and infected plants counted. Seedlings from both lots of treated seed sown were normal in appearance and in weight and the ability to germinate in each case was good (Table IV). The counts of infected plants are given in Table IV. There was no important effect on percentage plants infected. The short-wave radiation dose given to lettuce seed reduced the number to two thirds that in the case of untreated seed.

TABLE IV
EFFECT OF SHORT-WAVE RADIATION ON VIRUS INFECTED SEED
(a) Effect on Seed Itself

	Experiment	No. of Infected Plants per 100	
		Seed exposed to Short-wave Radiation	Control Seed
Tomato seed	1	0	2
	2	2	0
Lettuce seed	1	12	21
	2	22	33
	3	19	17

(b) Effect on the Seedlings.

Treatment	No. of Seeds which had germinated out of 45, 17 days after Sowing	Appearance of Seedlings	Average Weight of Seedling
Tomato seed exposed to short-wave radiation	38	Normal	0.059 gm.
Control seed	40		0.064 gm.
Lettuce seed exposed to short-wave radiation	15	Normal	0.073 gm.
Control seed	24		0.067 gm.

Flower-distorting Virus in Chrysanthemum (Chrysanthemum Mosaic)

Foliar Symptoms

It was intended to infect heat-treated plants and compare the foliage with that of controls, but the attempt to inoculate the plants was unsuccessful.

Incubation Period of Floral Symptoms

The incubation period of floral symptoms of flower distorting virus in the chrysanthemum is worth determining since if greater than one year measures against aphides need not be taken, provided plants for cuttings for the next season are kept free from aphides. In determining the incubation period attempts were made to infect plants with the virus by mechanical transmission and by insect transmission.

Twenty-four heat-treated Late Delight chrysanthemum plants were treated with virus on May 15th, 1953. One of these plants became infected. On November 3rd, 1953, the infected plant had a slightly tousled bloom. On November 30th, 1953, the same plant had a yellowish bloom (it should have been pale pink) having yellow streaks. The florets were narrower than normal.

Unsuccessful attempts at infecting plants by insect transmission were made.

Detection of the Virus

It was thought that *Physalis angulata* plants would be more suitable as test plants than *Nicotiana glutinosa* plants. Plants of the former species were treated with virus at the end of March. Eight days later there were yellowish areas, probably fused circles on the leaves. Ten days after treatment

with virus yellowing of the veins and mottling of the head had developed. As the symptoms appeared no earlier than symptoms on *N. glutinosa* treated with the same virus at the same time there is no advantage in using plants of *P. angulata* as test plants.

An attempt was made to reduce the incubation period (up to five weeks) of symptoms on *N. glutinosa* in the case of a test carried out in winter. It was hoped to make test plants more susceptible to virus infection by growing them from heat-treated seed. Various heat treatments were given. Plants from treated and from untreated seed were inoculated with virus. The treatments and effects on incubation period are given in Table V. There was no effect on the incubation period. The plants from treated seed were normal and so it appears that more drastic treatment is necessary: the water content of the seeds, which are individually minute, may be low.

TABLE V

EFFECT ON INCUBATION PERIOD OF SYMPTOMS DUE TO CHRYSANTHEMUM FLOWER DISTORTING VIRUS IN NICOTIANA GLUTINOSA PLANTS WHEN THESE ARE GROWN FROM HEAT-TREATED SEED

Treatment		Date of Inoculation	Date	No. of Plants showing Symptoms of Infection	
Temperature ° F.	Duration (Days)			Plants from Treated Seed	Plants from Untreated Seed
142.5	12	5/4/54	15/4/54	11 out of 18	9 out of 18
152.5	12	5/4/54	13/4/54	8 " " 18	10 " " 18
162.5	12	5/4/54	13/4/54	3 " " 18	7 " " 18
			15/4/54	14 " " 18	16 " " 18
172.5	12	5/4/54	13/4/54	12 " " 18	15 " " 18

The seed was sown in autumn but winter held up germination and growth.

III. ENTOMOLOGICAL INVESTIGATIONS

1. RED SPIDER-MITE [*Tetranychus telarius* (L.) Koch]

By W. J. PARR, C. CROCKER, and E. R. SPEYER

Owing to other commitments, it was not found possible to continue the research upon the bionomics of Red Spider-mite until October, when the great majority of adult mites obtainable were entering the hibernating phase.

(1) Mites deprived of Food, but with access to Water

With a view to obtaining further information upon the reproductive capacity of the mite when deprived of food but given access to water, female mites in the deuteronymph resting-stage were collected from French bean and tomato plants and placed, some upon discs cut from leaves of the former plant, and others upon waxed cork discs (see Annual Report, 1951, p. 42) through a small hole in the centre of which a fine wick had been passed, the object of this being to enable the mites to obtain a continuous supply of water without having to come in contact with that upon which the disc was floating. Both leaf and cork discs were $\frac{3}{4}$ -in. in diameter and the latter $\frac{1}{8}$ -in. in depth. The experiments were conducted in the laboratory.

(a) On September 30th, 12 female deuteronymphs were transferred from bean plants to floating leaf-discs of bean. All performed the ecdysis to the adult stage between October 1st and 5th. Eight of the adult mites, each kept upon a separate disc, assumed the brick-red colour of the hibernating phase from 4–8 days (average 5.5 days) after the ecdysis, and deposited no eggs during the subsequent very considerable period of time during which they were kept under observation and remained alive; only one of these mites spun any large amount of webbing over the leaf surface. Of the other mites, three, kept together upon one leaf-disc and transferred to a fresh disc respectively after successive periods of eight, three, and 10 days, deposited in all 61 eggs over an oviposition period of some 16 days; their average span of life was 22 days (range 18–25 days), and the first egg laid by each was deposited 2–4 days after the ecdysis.

The remaining mite, isolated on a leaf-disc upon which it spun a considerable quantity of webbing on the second day, deposited four eggs between the third and fifth day after the ecdysis, and was then transferred to a floating cork disc; upon the following day it laid one more egg after which it remained alive for a further period of 10 days, during which no further eggs were laid.

All the eggs laid by these mites were white in colour and opaque, and the four mites which deposited them retained the pale yellow colour of the summer form throughout their lives.

(b) On September 30th, 12 female deuteronymphs were placed, three together, on each of four floating cork discs; one mite died at the ecdysis to the adult stage, and the remainder performed the ecdysis within a period of five days. The average life-span of the 11 adult mites was nine days (range 7–11 days), during which they were very active though they had a shrunken appearance towards the end of their lives. No eggs were deposited, and but little webbing was spun over the cork surface. A few days after the ecdysis, the majority of the mites became of a dull orange-red tint, but none of them assumed the full brick-red colour of the hibernating phase.

(c) On October 10th, 11 female deuteronymphs collected from tomato plants were placed upon floating discs cut from bean leaves. All performed the ecdysis to the adult stage within a period of four days. Feeding-marks made their appearance upon the discs from 1–4 days after the mites had attained maturity. All the mites, which spun but little webbing over the discs, assumed the brick-red colour of the hibernating phase in from 3–7 days (average 5–6 days) after the ecdysis; no eggs were deposited during the period of 11 days over which the adult mites were kept under observation, and at the termination of which all were alive.

These very restricted observations would appear to furnish some evidence in support of the conclusions arrived at from previous experiments, to the effect that the female mite is unable to deposit eggs unless it is able to obtain some special form of nutrient from the leaf-tissues of plants which it inhabits. When deprived of all food, but given access to water, the adult mite of the summer form was able to live in an active state for a period of some nine days, presumably upon a store of nutriment which had been accumulated in the body during the deuteronymph stage, but was unable to produce eggs by virtue of this particular form of nutrient.

From the results of the experiments described above, it is suggested that the adult female mite requires food in order for it fully to assume the brick-red colour of the hibernating phase, and that the spinning of webbing, at least in large quantities, is neither a necessity nor an habitual preliminary to the mite entering that phase.

Since the mites used in the experiments were unmated, it became clear that the assumption of the brick-red colour was not dependent upon fertilisation by the male.

(2) Reactions of Mites to Air Currents

In 1758, Linnaeus stated that the mite to which he gave the specific name "*telarius*" inhabited plants grown in "forcing" houses, and occurred upon outdoor plants in situations little exposed to winds. An attempt was therefore made to observe the effect upon them of keeping adult female mites upon a tomato pot-plant, enclosed under a bell-jar through which, by means of a water siphon-pump, a continuous current of air was passed at a rate of about 0.35 feet linear per minute, over a period of seven days. The surface of the soil, contained in the 9-in. diameter pot in which the plant was growing, was covered with a sheet of plastic material, and the rim of the bell-jar was sealed to this with vaseline; air was admitted and drawn out by means of glass-tubing passed through the rubber cork closing the top of the bell-jar. The plant was 9 ins. in height and had eight leaves expanded.

To act as a control, another plant 10 ins. in height, with nine leaves expanded, was enclosed in a cellophane insect-cage of approximately the same size and cubic capacity as the bell-jar.

The two plants were kept next to each other upon a bench in the laboratory, and during the daytime such sunlight as prevailed was allowed to fall upon them.

Hygrometers introduced into the bell-jar and the cage gave an atmospheric humidity of 98 per cent. in the former and 100 per cent. in the latter during the course of the experiment.

Upon the day before the experiment was started on October 8th, 10 adult female mites of a yellow or greenish colour, but of unknown age, collected from tomato plants were distributed similarly upon each of the two pot-plants from the third to the seventh leaf from the base of each, a single mite being confined to the leaflet upon which it had been placed by a ring of vaseline encircling the stalk of that leaflet.

On October 15th, these leaflets were examined with the following results:—

(a) Upon the plant subjected to the air-current; nine mites, one of which had deposited a single white egg, had assumed the red colouration of the hibernating phase; of these mites, three had spun a large quantity of webbing round the edges and particularly over the *upper* surface of the leaflets, three a lesser but noticeable quantity, and three at most small quantities upon the lower surface. The remaining mite was dark brown in colour, and had deposited 29 dark brown eggs upon the under side of the leaflet, over which it had spun little or no webbing. All 10 mites were active.

(b) Upon the plant in the still air, six mites, all active, had assumed the red colouration of the hibernating phase, had deposited no eggs, and spun no noticeable quantity of webbing; of the remaining four mites, all of which were of a dark-brown colour and had spun no appreciable quantity of webbing, one was moribund and had laid no eggs, and three which were active had deposited respectively 19, 13 and 11 eggs.

All these eggs were of a dark brown colour, and of the total of 43, 15 had been laid upon the upper surface of the leaflets.

From a single experiment carried out at an inappropriate season of the year, conclusions naturally cannot be arrived at; it is, however, noteworthy that some of the mites upon the plant under the bell-jar through which the current of air had been passed, had spun a quite abnormal quantity of webbing, and this over the upper rather than the under surface of the leaflets to which they had been confined.

2. TRANSMISSION OF CHRYSANTHEMUM FLOWER-DISTORTING VIRUS BY APHIDS

By W. J. PARR, C. CROCKER and E. R. SPEYER

The object of the experiments here described was to determine if flower-distorting virus is likely to be transmitted from plant to plant through the agency of aphids which occur commonly upon chrysanthemum.

From a number of aphid species obtained through the kindness of Mr. L. A. Lickerish (Messrs. Pest Control Ltd.) at the end of April, *Coloradoa rufomaculata* Wilson and *Macrosiphoniella sanborni*

Gill. were selected, since these two insects are not only common pests upon commercial nurseries, but neither of them is known to breed upon plants other than *chrysanthemum*.

A third species, *Brachycauda helichrysi* Kalt., of somewhat less restricted habitat, was included in the experiments, for, at the beginning of April, the insect was available upon rooted cuttings, both out-of-doors and under glass, at the Cheshunt Station. Stocks of these aphids were maintained upon a succession of plants kept in a small greenhouse. The experiments were conducted in cages, and at the conclusion of each, the plants used in them were freed from the insects by fumigation and grown on in a separate glasshouse. Dr. R. Howles provided virus-infected pot-plants of variety Late Delight raised from cuttings during the previous autumn or, in the later experiments, from cuttings taken from virus-infected plants of other varieties, and tested all the plants shortly before or after the time at which each experiment was performed. The virus-free plants to which the insects were transferred after a sojourn upon infected ones were tested for the virus at periods of two to four months after the completion of each experiment.

There was no evidence to indicate that any one of these three aphid species was operative as a vector of the virus.

(1) *Brachycauda helichrysi* Kalt.

During April, alatae produced their young within the growing-points of rooted cuttings; the insects fed principally upon the upper surface of the unfolding leaves and the injury caused to them resulted in a distortion which later gave the plants the appearance of having become infected with some kind of virus. Tests showed, however, that no virus was present. When there was no longer living-room for them in the growing-points, the insects formed colonies of considerable size upon the stems beneath them. The preponderance of alatae in the successive generations was so great that insufficient numbers of apterae were available for use in the experiments. During August the colonies died out.

In a preliminary experiment, a single alate with its young was located upon a virus-infected plant on April 9th. The parent alate was transferred to one virus-free plant, and its young, to the number of about 40, to another. By April 16th the alate had produced 12 more young.

On June 22nd the original plant from which the insects had been obtained again gave a positive, but both plants to which they had been transferred gave a negative test for the virus.

(a) On May 20th, 50 alatae previously starved for a period of 29 hours were liberated upon a virus-infected plant, which was then surrounded by five virus-free rooted cuttings each some 6 ins. in height. By June 23rd all the plants had become heavily infested by the insects.

Tests carried out on August 27th gave a positive one for the original virus-infected plant, and a negative one for each of the five virus-free plants.

(b) In two experiments carried out in early August, the virus-free plants to which the aphids were transferred were five-week-old cuttings of variety Late Delight, 4-5 ins. in height.

Thirty alatae, taken straight from virus-free stock-plants, were allowed to remain for a period of 48 hours upon a virus-infected plant, and were then transferred to a virus-free plant. After a period of 48 hours, 23 alatae with some young which they had produced were present upon the latter plant. Two months later, this plant gave a negative test for the virus.

Upon each of two virus-infected plants, 30 alatae previously starved for three hours were allowed to remain for 5-10 minutes. The insects were then transferred to two virus-free plants upon which, after a period of 48 hours, 22 alatae were present on one, and 25 upon the other plant.

Two months later, both these plants gave a negative test for the virus.

(2) *Coloradoa rufomaculata* Wilson

The insect at first lived and produced young upon the under-surface of leaves low down upon the plant, and even after it had, by early June, bred to such an extent that practically no leaves remained untenanted, but few were found upon the upper surface of the foliage. The honey-dew secreted by the aphids caused the foliage to become sticky. No massed colonies were formed upon the stems of the plants. Alatae were prevalent until July, and apterae from August until the end of September.

(a) On July 6th, 40 alatae, taken straight from virus-free stock-plants, were allowed to remain for a period of 48 hours upon a virus-infected two-month-old rooted cutting, 8 ins. in height, taken from a plant which had given a positive test for the virus. They were then transferred to a virus-free two-month-old rooted cutting of variety Late Delight, 9 ins. in height. After a period of 48 hours, 36 alatae with young which they had produced were present upon the latter plant.

On September 9th this plant gave a negative test for the virus.

(b) In three experiments carried out in September, the virus-infected plants were nine-week-old rooted cuttings, 6–7 ins. in height, taken from a plant which had given a positive test for the virus; the virus-free plants to which the aphids were transferred from the latter were 9–11 week-old rooted cuttings of variety Sussex Bronze, 7–8 ins. in height.

Forty apteræ, taken straight from stock-plants, were allowed to remain upon a virus-infected plant for a period of 48 hours, and were then transferred to a virus-free plant. After a period of 48 hours 34 apteræ, with some young which they had produced, were present upon the latter plant.

Forty apteræ previously starved for a period of three hours were allowed to remain upon a virus-infected plant for 15–20 minutes, and were then transferred to a virus-free plant. After a period of 48 hours, 38 apteræ with some young were present upon the latter plant.

One hundred and forty apteræ, previously starved for a period of five hours, were allowed to remain upon a virus-infected plant for a period of 20 hours, and were then transferred to a virus-free plant; after three days 116 apteræ, which had produced large numbers of young, were present upon the latter plant.

Three and a half to four months after completion of each experiment, the virus-free plants to which the aphids had been transferred all gave a negative test for the virus.

(3) *Macrosiphoniella sanborni* Gill.

This large aphid, commonly known as "Chrysanthemum Black-fly," was bred from two or three apteræ which produced their young in the growing-points of stopped plants. Later, colonies containing many hundreds of the insects were formed round the stems. During July, alata were prevalent, and from August onwards until the end of September alata and apteræ were produced in about equal proportions.

(a) In two experiments started on July 2nd, the virus-infected plants used were two-month-old rooted cuttings, 8–9 ins. in height, taken from a plant which had given a positive test for the virus; the virus-free plants to which the insects were transferred from the latter were two-month-old rooted cuttings of variety Late Delight, 8–9 ins. in height.

Forty alata, taken straight from virus-free stock plants, were allowed to remain upon a virus-infected plant for a period of 48 hours, and were then transferred to a virus-free plant. After a further period of 48 hours, 37 alata with some young which they had produced were present upon the latter plant. On September 9th this plant gave a negative test for the virus. Upon each of two virus-infected plants 40 alata, previously starved for a period of three hours, were allowed to remain for 5–10 minutes. The insects were then transferred to two virus-free plants. After a period of 48 hours, respectively 36 and 38 alata with a number of young which they had produced were present upon the latter plants.

On September 9th both these plants gave a negative test for the virus.

(b) In two experiments started on September 3rd, the virus-infected plants used were nine-week-old rooted cuttings, 6 ins. in height, taken from a plant which had given a positive test for the virus; the virus-free plants to which the insects were transferred from the latter were nine-week-old rooted cuttings of variety Late Delight, 10 ins. in height.

Forty apteræ, taken straight from stock-plants, were allowed to remain upon a virus-infected plant for a period of 48 hours, and were then transferred to a virus-free plant. After a further period of 48 hours, 36 apteræ with some young which they had produced were present upon the latter plant. On November 16th, this plant gave a negative test for the virus.

Forty apteræ, previously starved for a period of three hours, were allowed to remain upon a virus-infected plant for 15–20 minutes, and were then transferred to a virus-free plant. After a period of 48 hours, 34 apteræ with some young which they had produced were present upon the latter plant.

On November 16th, this plant gave a negative test for the virus.

(c) In two experiments started on September 14th, the virus-infected plants used were 11 week-old rooted cuttings, 5 ins. in height, taken from a plant which had given a positive test for the virus; the virus-free plants to which the insects were transferred from the latter were 11 week-old rooted cuttings of variety Sussex Bronze, 8–9 ins. in height, taken from a plant which gave a negative test for the virus.

The insects, previously starved for a period of five hours, were allowed to remain upon the virus-infected plants for a period of 20 hours, and were then transferred to the virus-free plants, upon which they were left for a period of three days.

In one experiment, 130 alata were transferred from a virus-infected to a virus-free plant, and upon the latter 120 alata and some 160 young which they had produced were present at its termination.

In the other experiment, 200 apteræ were transferred from a virus-infected to a virus-free plant, and upon the latter, 196 apteræ and 203 young which they had produced were present at its termination.

Three to four months after completion of both experiments, the virus-free plants to which the aphids had been transferred gave negative tests for the virus.

3. A SCIARID FLY INJURIOUS TO SEEDLINGS

By W. J. PARR, C. CROCKER and E. R. SPEYER

Much injury was caused, during the winter months, to seedlings of tomato and *Nicotiana* grown in the heated glasshouse used for breeding of the White-fly parasite at the Cheshunt Station, by larvæ of a Mycetophilid fly. This insect was determined, through the kindness of the Commonwealth Institute of Entomology, as belonging to the species *Sciara modesta* Staeg. The larvæ of the fly fed upon the root-hairs of very young seedlings, as a result of which their growth became greatly retarded, and sometimes they caused collapse of plants by tunnelling into the stem.

An opportunity was thus afforded of making some observations upon the habits of the adult fly, and of assessing at recorded temperatures the periods of time occupied in incubation of the egg, each of the four larval, and the pupal instars.

Results of experiments indicated that control, but not total eradication, of the insect could be obtained by application of Parathion in very dilute solution to the soil in which the seedlings were being raised.

Bionomics of the Adult Flies

Even when kept under seemingly natural conditions but confined in glass tubes, up to 1 in. in diameter, inverted over moist soil or powdered horse manure, with the upper end covered with muslin, single female flies, or pairs of each sex, newly emerged from the pupæ, remained alive for comparatively short periods of time.

Of six males kept under these conditions, one survived for seven days, and the remainder for from three to six days; for six mated and five unmated females the period of survival was four to six days. A male and female fly confined together were observed to pair a few hours after emergence from their respective pupæ, and the pair remained in coitu for six minutes; the male subsequently survived for five and a half and the female for eight and a half days, and the single egg deposited failed to hatch. Before emergence from the pupa, the bodies of female flies were, by dissection, found to contain large numbers of fully mature eggs. An unmated female, confined in a tube over moist soil, deposited no eggs, though, after it had died, its abdomen contained at least 70 eggs. Eggs occasionally deposited by unmated females were never viable.

When kept under conditions presumably of excessive moisture, or accidentally injured, females, whether mated or not, would sometimes rid themselves at least of the majority of their eggs. An unmated female deposited some 100 eggs during the period of five days over which it survived in a small glass cell containing powdered horse manure; none of these eggs were viable. Of two females previously kept with males newly emerged from pupæ, one confined in a glass tube containing moist filter-paper voided itself of 136 eggs within a period of five hours, and the other, which had been accidentally injured, of 137 eggs in 43 minutes; none of these eggs hatched subsequently.

Viable eggs, in numbers ranging from some 15–30 per female, were obtained by confining a pair of each sex in a glass tube $\frac{1}{2}$ in. in diameter, one end of which had been plugged to a height of $\frac{1}{2}$ in. with soil or coarsely powdered horse manure and sunk into moist sand, and the upper end covered with muslin. The female flies with few exceptions deposited these numbers of eggs whether kept in light or darkness, in the laboratory at a mean temperature of 59° F., or in an incubator at a constant temperature of 72° F.

Under more natural conditions, e.g. when the flies were confined under lamp-glasses inverted over moist soil contained in petri dishes, the eggs were usually laid in small groups, either beneath the soil surface or in crevices, and only rarely in more exposed situations.

The Egg

The eggs, of a pale lemon colour and later becoming translucent and whitish, were oval in shape, with an average length of 0.23 mm. and greatest diameter of 0.13 mm.

To observe the period of incubation, small groups of them were marked by means of fine paper strips and examined at frequent intervals of time under a low-power binocular microscope.

The periods at the recorded temperatures given were as follows:—

Means between 58° F. and 60° F. (range 50°–71° F.), 9–12 days, assessed from a large number exposed to daylight.

Mean 61.5° F. (range 50°–71° F.), 8–9 days for 28 eggs exposed to daylight, 9–10 days for 31 eggs kept in darkness.

Mean 64° F. (mean of 57° F. during early part of incubation, and 72° F. constant afterwards), 6–7 days assessed from a large number kept in darkness.

At 72° F. constant, 4–5 days assessed from some 50 eggs kept in darkness.

The results obtained indicated that exposure to light had no influence upon the period of incubation which is likely to be about six days in a glasshouse heated during the winter months.

The Larval and Pupal Instars

(a) Larvæ obtained from eggs which had been deposited between November 20th and 27th by a mated female fly were kept in the moist soil, contained in a covered petri-dish, in which the eggs had been laid.

A mean temperature of 58° F. (range 50–70° F.) was recorded over the period from hatching of the first eggs on December 1st to emergence of the first adult flies on January 6th. This gave a minimum period of some 35 days for development of the larval and pupal instars together.

The periods of development for two male and 11 female pupæ, obtained from larvæ collected from the soil of pot-plants between November 20th and 24th and kept on moist wool at a mean temperature of 58.5° F. (range 50–71° F.), were respectively 8.5 (range 8–9 days) and 7.7 (range 6–9 days).

The minimum period occupied in development of the larval instars at a mean temperature of 58° F. may therefore be computed as some 27 days.

(b) Larvæ obtained from eggs deposited between December 5th and 8th by another mated fly were kept under conditions similar to those previously indicated, but in an incubator at a constant temperature of 72° F.

The first eggs hatched on December 12th, the first larvæ were observed to pupate on January 15th, and the first flies emerged on January 19th, giving a minimum period of some 37 days for development of the larval and pupal instars together.

The average period of development for 15 pupæ, obtained during the ensuing 18 days and from all of which female flies emerged, was 3.4 (range 3–4) days, so that the period occupied in the larval instars had ranged approximately from 34 to 50 days.

The considerable increase in dimensions and the general appearance of the larvæ after each ecdysis made it possible, with some degree of accuracy, to separate the instars from one another. Average measurements of the length in mm. were: 1st instar, 0.8; 2nd instar, 1.4; 3rd instar, 3.0; 4th instar, 5.3. A pair of spiracles was situated upon the prothorax in all the instars, but the abdominal somites of 1st and 2nd instar larvæ, mounted for microscopic examination, appeared to be devoid of spiracles. Doubtfully in the 3rd, but certainly in the 4th instar, a pair of spiracles was situated upon each of the first to seventh abdominal somites, their peritremes being smaller than those of the spiracles upon the prothorax.

Measurements given in Table I, of the width of the head capsule, confirmed that the larvae passed through four instars during their development to the pupal instar, according to the principles of Dyar's Law:—

TABLE I
WIDTH OF LARVAL HEAD CAPSULES IN μ
Average ratio of increase=1.43

Instar	Calculated	Observed Width		No. of Measurements
	Width	Mean	Range	
1st	—	88	86–89	9
2nd	126	114	112–114	5
3rd	180	178	—	6
4th	257	257	229–279	6

Following the technique adopted by R. S. Pitcher (Journ. S.E. Agric. Coll., Wye, Kent. 38 pp. 83–84, 1936) for *Sciara fenestralis* Zett. attempts were made to rear isolated larvæ in circular glass cells cemented to microscope slides and containing small quantities of powdered horse manure placed upon circles of moist filter-paper, a coverslip resting upon the rim of each cell to which vaseline had been applied, serving as a lid. The larvæ in the cells were examined twice daily. In some instances, a small piece of starch agar (pH 7.0) was substituted for horse manure, but, with one exception, all the larvæ died before completing the ecdysis to the 2nd instar; one spent 11 days in the first, and eight days in the 2nd instar, and then remained in a moribund condition until it died after a further period of 14 days. Reared under these conditions upon horse manure, none of the larvæ kept in the

laboratory, in which a mean temperature of 58° F. was recorded, developed beyond the 3rd instar; the periods of time occupied in the first two instars again were 11 and eight days.

When the cells were kept in an incubator at a constant temperature of 72° F., some of the larvæ not only completed their development to the pupal instar, but adult flies were subsequently obtained from the pupæ.

Of three larvæ which hatched between December 14th and 15th from eggs laid by a single fly, one was reared to the adult stage. The periods of time occupied in each of the four larval instars were respectively eight, three, seven, and 23 days (total 41 days), and in the pupal instar four days; from the pupa a female fly emerged on January 29th. The other two larvæ survived only to the 3rd instar, with periods of 7-8 and 2-5 days respectively in the 1st and 2nd instars.

Of eight larvæ hatched on January 13th from eggs laid by another fly, four were reared to maturity, the adult flies obtained from the pupæ all being of the male sex. The periods occupied in each instar are shown in Table II:—

TABLE II
DURATION OF LARVAL AND PUPAL INSTARS IN DAYS, AT 72° F. CONSTANT
Eggs hatched, 13.I.54

Larva			Larval Instars					Pupal	Male Fly
No.			1st	2nd	3rd	4th	Total	Instar	Emerges
1	...	...	4	3	3	7	17	4	3·II
2	...	...	5	4	2	3	19	4	5·II
3	...	...	5	4	2	9	20	4	6·II
4	...	...	5	5	3	11	24	3	9·II
Average	...		5	4	3	9	20	4	—

Of the four remaining larvæ, three survived only to the second, and one reached the 4th instar; the periods of time occupied in each completed instar did not differ from those of the larvæ which were successfully reared to maturity. It was suggested by these observations that differences in temperature did not constitute the only factor responsible for the considerable variability, exhibited especially by larvæ in the last instar, in the duration of the larval life. There was a possibility, though a remote one, that development of male was much more rapid than that of female larvæ.

Pitcher (loc. cit. p. 85) recorded similar variation in rate of development for 4th instar larvæ of *S. fenestralis* reared at a constant temperature in the region of 72° F., and attributed this to periods of inactivity brought about by conditions unfavourable to them. He noted that deficiency of moisture caused the larvæ to spin threads which formed a cocoon-like covering over them.

The larvæ of *S. modesta* were also observed, from time to time, to spin a silken cocoon into which particles of debris and earth were woven; in this they remained inactive for periods up to 24 hours before performing the ecdysis to the pupal instar. Others entered this quiescent phase without spinning cocoons.

Effect of Parathion upon Larvæ and Pupæ in the Soil

Early in November, experiments were conducted with a view to determining if Parathion could be applied to the soil of boxes and pots, in which seedlings of tomato (variety Vetomould) and of Nicotiana (White Burley) were being raised, at dilutions which would kill larvæ and pupæ of *S. modesta* without causing injury to the plants.

As a result of damage caused to the roots by the large numbers of larvæ present to a depth of about $\frac{1}{2}$ in. in the soil, the growth of the tomato seedlings had been greatly retarded, and the seedlings of Nicotiana were rapidly dying off.

Parathion diluted at rates respectively of one part in one hundred thousand and one part in fifty thousand parts water was applied by means of a watering-can provided with a fine rose so as thoroughly to drench the soil of the boxes and pots in which the plants were growing; as controls for comparison, plants of the same or nearly the same age received water applied in a similar manner. For each of the two concentrations of Parathion and for the control, one box of tomato seedlings and three "60" size pots each containing a young Nicotiana plant recently potted in fresh soil received treatment.

At the time of application, the tomato seedlings were $\frac{3}{4}$ –1 $\frac{1}{4}$ in. in height with the first pair of secondary leaves just showing; the Nicotiana plants had developed three to four leaves with span ranging from 1 to 2 $\frac{3}{4}$ ins.

Eight days later, the height of the tomato seedlings treated with Parathion at both concentrations had increased on the average by $\frac{3}{8}$ in. and the secondary leaves had an average span of some 2 $\frac{3}{8}$ ins.,

while the height of those in the control box had increased on the average only by about $\frac{1}{4}$ in. and the average span of the secondary leaves was about $1\frac{1}{2}$ in.

Both in the pots treated with Parathion and in the controls, the *Nicotiana* plants had expanded an additional leaf, and the older leaves showed an average increase in expanse of about $1\frac{1}{2}$ ins.

It thus became evident that treatment with Parathion at both the concentrations used had not adversely affected the growth of the plants; there were indications also that the activities of the larvæ in the soil of the tomato boxes had been brought, at least temporarily, to a standstill.

During the period over which these observations extended, a mean temperature of 55.5° F. (range $48-68^{\circ}$ F.) was recorded in the glasshouse in which the experiments were carried out.

To observe the effect of Parathion at each of these concentrations upon the larvæ and pupæ of the insect, similar treatment was given to the soil of "60" size pots in which *Nicotiana* seedlings had recently died off.

At intervals respectively of two and six days after treatment, 100 g. samples of the soil to a depth of $\frac{1}{2}$ in. from the surface were taken from each pot, and counts made of the active, moribund, and dead larvæ in them; pupæ collected from each sample were placed upon moist wool and subsequent emergence of adult flies from them was recorded.

The following results were obtained:—

- (a) Samples examined two days after treatment; soil comparatively dry at time of application.
 Concentration 1 : 100,000. Larvæ, 37 moribund, none active or dead; no pupæ present.
 Concentration 1 : 50,000. Larvæ, 135 moribund, 13 dead, none active; 2 pupæ, from one of which a male fly emerged after seven days.
 Control. Larvæ, 140 active, none moribund or dead; 3 pupæ, from two of which male flies emerged respectively after three and seven days.
- (b) Samples examined six days after treatment; soil moist at time of application.
 Concentration 1 : 100,000. Larvæ, 40 moribund, 108 dead, none active; pupæ 20, from none of which flies emerged, though four appeared to be alive when collected.
 Concentration 1 : 50,000. Larvæ, 71 moribund, 162 dead, none active; pupæ, 5, from none of which flies emerged.
 Control. Larvæ, 27 active, 6 inactive, 1 dead; pupæ 32, from which seven male and 18 female flies emerged after periods of 2-7 days; from seven no flies emerged.

It was concluded from these experiments that application of Parathion at a concentration of one part in fifty thousand parts water could be expected to destroy at least the majority of larvæ in the soil without risk of injury to seedlings of tomato and *Nicotiana*; adult flies, however, emerged from some of the pupæ, so that more than one application would be necessary to ensure complete eradication of the insect.

4. ROOT-KNOT EELWORM (*Heterodera marioni* Cornu)

By W. J. PARR, C. CROCKER and E. R. SPEYER

In March, dispersible Parathion at a concentration of approximately one part in 2,700 parts water was applied by hose at a rate of 1 gall. per sq. yd. to the recently dug-over soil of one border and half of the undug path adjoining it, of a greenhouse 20 ft. long by 13 ft. wide with path 5 ft. wide; to the opposite border and other half of the path, water was applied at a similar rate.

Roots of tomato plants in the area treated with Parathion had been infested with the eelworm during the previous growing season; the untreated area had lain fallow since the previous year, and into the soil of this a few infested tomato roots were dug shortly before Parathion was applied to the other border. One month after treatment, both areas were planted up, each with 30 plants of variety E.S.1 (from "60" size pots) at normal spacing, base fertilizers having been incorporated in the soil.

Subsequently, one plant in the treated area, and six plants in the untreated one were lost, through fungus disease and other causes.

In October, the plants were lifted and the roots examined for eelworm galls with the following results:—

- (a) Area treated with Parathion, 29 roots—two each with some 50 larger galls, two each with some 10 large galls, two each with one to two large and some minute galls, three each with a few small galls; 20 roots uninfected. Of the six plants the roots of which carried large galls, five were in the row immediately adjoining the path, and one (with two large and some 30 small galls) was situated at a corner of the row nearest to the wall of the greenhouse; no other plants in the latter row showed any sign of infestation.

(b) Untreated area, 24 roots—one with some 10 large galls, four each with one large and up to three small galls, one with two small galls; 18 roots uninfected. The two plants the roots of which carried the greatest number of galls were situated in the row adjoining the path; of the other infected plants, two were in the middle row, and two in that nearest to the wall of the greenhouse. All the infected plants were in a prescribed area in which infected roots had previously been introduced into the soil.

It would appear probable that the application of Parathion had had some effect in reducing the eelworm population in the treated border, but had not destroyed the eelworm present in the undug path, into the subsoil of which the roots of the most severely infected plants had penetrated.

Mr. J. T. Hughes, of the Insecticide Department, kindly undertook the application of the Parathion.

IV. INSECTICIDES & FUNGICIDES

By W. H. READ, J. T. HUGHES and R. J. SMITH

I. ACARICIDES

The laboratory investigations of the intrinsic toxicities of a series of nine chlorinated phenyl benzene sulphonates to eggs of the glasshouse red spider *Tetranychus telarius* have been concluded and a detailed account of the work has been published elsewhere.¹ The toxicities were determined by the method described by Read and Wain,² in a series of assays designed as balanced incomplete blocks so that each compound was tested once against every other compound, and, in all, four times with the exception of 2 : 4-dichlorophenyl 2 : 4-dichlorobenzenesulphonate which was tested on three occasions.

The above compound and also 2 : 4-dichlorophenyl 4-chlorobenzenesulphonate and 4-chlorophenyl 2 : 4-dichlorobenzenesulphonate were of such low ovicidal potency that in the analysis of the results, very kindly undertaken by Dr. S. C. Pearce, of East Malling Research Station, it was necessary to ignore the differences between occasions.

The results showed that, taking the L.D.95 level (i.e. the concentration causing 95 per cent. mortality of eggs) as the criterion of activity, the activities of phenyl benzenesulphonate, 4-chlorophenyl benzenesulphonate, 4-chlorophenyl 4-chlorobenzenesulphonate, 2 : 4-dichlorophenyl benzene sulphonate and phenyl 2 : 4-dichlorobenzenesulphonate did not differ significantly in these tests. The second of these compounds, usually referred to as PCPBS but preferably termed CPBS, is now extensively used in Britain for the control of red spider on tomatoes and carnations. 4-chlorophenyl 4-chlorobenzenesulphonate, to which the proprietary name "Ovotran" has been given, and 2 : 4-dichlorophenyl benzenesulphonate, stated to be the active principle in the proprietary product "Miticide 923" are both employed for the control of various species of mites.

Trials were commenced to determine the relative phytotoxicities of the above compounds to glasshouse plants. Preliminary tests showed that phenyl benzenesulphonate was considerably less injurious to cucumbers than the chlorinated derivatives possessing ovicidal potency and 4-chlorophenyl 4-chlorobenzenesulphonate appeared somewhat less injurious than CPBS (PCPBS).

Two newly introduced compounds for which ovicidal and acaricidal activities towards mites were claimed, 4-chlorobenzyl 4-chlorophenylsulphide ("chlorparacide")³ and ethyl 4 : 4'-dichlorobenzilate, were found to be of considerable promise for the control of red spider on tomatoes and carnations when applied as aerosols generated by spraying solutions of them in acetone with a paint spray gun. Practically complete control of red-spider mite on tomatoes was obtained with a single application of either compound at the rate of 4g per 1,000 cu. ft.

Both compounds were similar to 4-chlorophenyl benzenesulphonate in their effect on mites. Adults were not immediately affected but the persistence of the compounds, or of products derived from them, was sufficient to destroy all the eggs or larvae emerging from eggs deposited by adult females after treatment. Unfortunately both compounds were injurious to cucumbers at the 4g/1000 cu. ft. level tried in these preliminary tests.

Extensive comparative trials are necessary to decide the optimum dosage rates and relative merits of the several compounds now available for the control of red spider on tomatoes and other crops tolerant to these compounds.

Acknowledgments

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2. FUNGICIDES

(a) Laboratory Investigations

The *in-vitro* fungitoxic activities, against spores of *Fusarium culmorum*, of certain chlorinated 1 : 4-benzoquinone- and 1 : 4-naphthaquinone mono- and di-chloroimides have been investigated. 1 : 4-Naphthaquinone mono- and di-chloromides both proved to be considerably less toxic

than 2 : 3-dichloro-1 : 4-naphthaquinone ("Phygon") whereas 2-chloro-1 : 4-benzoquinone dichloroimide and, especially, 2 : 5-dichloro-1 : 4-benzoquinone dichloroimide were very nearly as toxic as the dichloro-naphthaquinone.

(b) Glasshouse Trials

TOMATO LEAF-MOULD

4-Amino-2-chlorophenol, reported as highly active against tomato leaf-mould (*Cladosporium fulvum*) in the Annual Report for 1952 as a result of preliminary tests, was further tested against leaf-mould in spray trials conducted on large tomato plants grown normally in glasshouse borders. The results of these tests were less favourable than those obtained in 1952 for, although the compound had a marked action on the older lesions, it failed to eradicate the fungus from recently infected areas and furthermore it had negligible protective action when applied at 0.3 per cent. in a spray formulation. Other chlorinated aminophenols were also examined but proved less effective than 4-amino-2-chlorophenol.

The investigation of the fungitoxic properties of compounds related to quinones, of which the above is part, has not disclosed any compound of sufficient merit to be considered for the replacement of existing fungicides for the control of tomato leaf-mould. These investigations have been concluded and a fuller account of the work will be published elsewhere.

CUCUMBER MILDEW CONTROL

A number of trials were made with a proprietary product, Karathane, stated to contain 25 per cent. of technical 6-capryl 2 : 4-dinitrophenyl crotonate, which showed considerable merit in small scale tests against cucumber mildew (*Erysiphe cichoracearum*) in 1952. In the 1952 tests the formulated product was applied at concentrations of 0.2 per cent., 0.1 per cent., and 0.05 per cent. and there appeared to be some hardening of the growth of young cucumbers at the 0.2 per cent. and 0.1 per cent. levels. Further tests have been made, therefore, to find if adequate control of cucumber mildew could be obtained with lower concentrations of the product and consequently with less risk of injury to plants.

In the first test, batches of eight young mildew-attacked cucumber plants in pots were sprayed with the proprietary product at dilutions of 0.05 per cent., 0.025 per cent., 0.012 per cent., and 0.006 per cent. A wetting agent containing 60 per cent. of dioctyl sodium sulphosuccinate was incorporated in the sprays at a concentration of 0.025 per cent. to give adequate wetting of the fungus. The plants constituting each batch were selected so that the severity of the disease in each batch was similar and no numerical assessment of the disease before or after spraying was undertaken. Unsprayed, mildew-infected plants were retained in the same glasshouse. In addition disease free cucumber plants were sprayed with the same dilutions of the fungicide in order to observe any injury to plants.

Examination of the plants 18 days after spraying showed that the disease was eradicated and new infections were absent on plants sprayed with the 0.05 per cent. dilution and that almost complete control was obtained at 0.025 per cent. There was, however, some new growth of mildew at the two lowest concentrations. Slight yellowing of the older foliage but no significant reduction of growth resulted from the application of Karathane at 0.05 per cent. to healthy plants, and there was no evidence of phytotoxicity at the lower concentrations.

Other tests were made in which the product was compared with a copper-petroleum spray widely used for the control of cucumber mildew. The results of these tests, which were made both on small plants in pots and on fruiting plants in borders, showed that the product when applied at 0.05 per cent. in conjunction with dioctyl sodium sulphosuccinate at 0.025 per cent. caused no more, and in some cases noticeably less injury to cucumber plants than a copper oxychloride-petroleum emulsion spray (0.06 per cent. Cu and 0.35 per cent. petroleum) and gave equal or superior control of cucumber mildew.

Didymella Stem-rot

Many compounds have been tested as eradicans against the lesions caused by the stem-rotting fungus *Didymella lycopersici* Kreb. on tomato plants. Most of the compounds were prepared in connection with other investigations but have been screened against *Didymella*.

Tomato plants (var. Potentate) about 18 ins. high and with a stem diameter of about 0.5 in. were inoculated at four internodal positions by the application of small pieces of mycelium from a culture of the fungus. The lesions developed rapidly and when 40–80 sq. mm. in surface area were treated with a paste containing one of the compounds. The pastes were prepared by triturating the finely ground compound (usually 15 to 25 per cent.) with kaolin (40 per cent.) and water. Each compound was tested on at least four fungal lesions.

Although certain compounds temporarily arrested the development of the lesions, in no case was the fungus within the plant tissues killed and, after a period of two or three weeks, normal development of the lesions resulted in the collapse of the plants.

The compounds tested and their concentrations in the paste are listed below. Compounds which injured plants when applied to the stems are marked with an asterisk.

QUINONES

2 : 3 : 5-Trichloro-1 : 4-benzoquinone	...	...	...	...	...	15%
2 : 3 : 5 : 6-Tetrachloro-1 : 4-benzoquinone	...	...	...	...	...	15%
2 : 3-Dichloro-1 : 4-naphthaquinone	...	...	...	...	...	20%
3-Nitro-1 : 4-naphthaquinone	...	...	...	...	...	20%
1 : 4-Naphthaquinone-4-chloromide	...	...	...	...	...	20%
1 : 4-Naphthaquinone-dichloromide	...	...	...	...	...	20%

HYDROXY COMPOUNDS AND DERIVATIVES

2-Chloro-4-nitrophenol	...	...	...	...	...	10%*, 3%
2-Chloro-4-nitrophenyl acetate	...	...	...	...	...	20%*
2-Chlorohydroquinone	...	...	...	...	...	20%*, 7%
2-Chloro-4-nitro-1-naphthol	...	...	...	...	...	10%
2 : 6-Dinitrohydroquinone	...	...	...	...	...	20%*
2 : 6-Dinitro-3-chlorohydroquinone (m.p. 134–5° C.)	...	...	...	...	...	15%
2 : 3-Dichloro-1 : 4-naphthahydroquinone	...	...	...	...	...	10%
2 : 4-Dichloro-1-naphthol	...	...	...	...	...	25%
2 : 5-Dichlorohydroquinone	...	...	...	...	...	15%
Salicylanilide	...	...	...	...	...	20%
2-Nitrohydroquinone	...	...	...	...	...	15%
2 : 3 : 5 : 6-Tetrachlorohydroquinone	...	...	...	...	...	20%
2 : 3 : 5-Trichlorohydroquinone	...	...	...	...	...	25%
2 : 4 : 6-Trichlorophenol	...	...	...	...	...	7%
2 : 4 : 6-Trichlorophenoxyacetic acid	...	...	...	...	...	10%

AMINOHYDROXY COMPOUNDS

4-Amino-2-chlorophenol	...	...	...	...	...	10%
4-Amino-2 : 5-dichlorophenol	...	...	...	...	...	15%
4-Amino-2 : 3 : 6-trichlorophenol	...	...	...	...	...	20%
4-Amino-2-nitro-1-naphthol	...	...	...	...	...	10%
4-Amino-2-nitro-1-naphthol hydrochloride	...	...	...	...	...	10%
4-Amino-2-nitro-3-bromo-1-naphthol	...	...	...	...	...	10%

DIAMINO COMPOUNDS

2-Chloro-1 : 4-diaminobenzene	...	...	...	...	...	20%
2-Chloro-1 : 4-diaminonaphthalene	...	...	...	...	...	10%
2-Nitro-1 : 4-diaminobenzene	...	...	...	...	...	20%
2 : 3 : 5 : 6-Tetrachloro-1 : 4-diaminobenzene	...	...	...	...	...	25%

MISCELLANEOUS COMPOUNDS

2 : 4-Dinitro-6-caprylphenyl crotonate (active principle of "Karathane")	...	...	...	...	...	10%
4-Chlorophenylhydrazine hydrochloride	...	...	...	...	...	10%
Zinc ethylene bisdithiocarbamate ("Zineb")	...	...	...	...	...	25%
N-Trichloromethylthiotetrahydrophthalimide (captan)	...	...	...	...	...	20%

3. ANALYTICAL INVESTIGATIONS

A study has been made of two methods of parathion estimation in plant tissue. Highly coloured extracts are first obtained by extracting macerated tissue with benzene. In the method first described by Averell and Norris¹ and in modifications of this method by Gunther & Blinn² and Wilson *et al.*³ these extracts are decolourised with adsorbent solids, an aliquot of the filtered extract is gently evaporated and an alcoholic solution of the residue used in a colorimetric estimation procedure. This entails the reduction of the parathion with zinc dust and hydrochloric acid to 0, 0-diethyl 0-*p*-aminophenyl phosphorothioate, which by diazotisation and coupling with N-naphthyl ethylene diamine yields an intensely coloured dye.⁶

In the alternative procedure developed by Gage, reduction to the amino compound is effected in the solvent extract with zinc dust and glacial acetic acid⁴ or benzoic acid.⁵ The amino compound is then extracted from the solvent phase with hydrochloric acid and estimated colorimetrically, after diazotisation and coupling. The acid extracts obtained in the second method are usually colourless and no solvent evaporation is required so that the overall time for the analysis is shorter. However, where a number of samples are treated simultaneously no advantage may be gained as each sample must be separately extracted with acid whereas in the first method the solvent-evaporation stage may be accomplished with little attention by the use of an arrangement of air jets. Full details of this work will be published elsewhere when the investigations are completed.

Chromatographic methods for separating parathion and some closely related esters have been investigated. By these methods very small quantities of the compounds (e.g. 10–100 µg.) have been separated and identified. Progress has been made in elucidating the effects of certain variables in these chromatographic processes and in the quantitative evaluation of the separated compounds. The methods are being applied to investigations of the products emitted from parathion smoke generators and preliminary work indicates that considerable decomposition of the contained parathion occurs during emission.

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4. PARATHION RESIDUES

(a) The Examination of Cucumbers grown in soil watered with Parathion

Parathion has been found to give good control of woodlice¹ and recent experiments have shown that control of the larvae of certain sciarid flies (dung-maggots) can be obtained by soaking the cucumber beds with dilute parathion (0.002 per cent.).

In view of these uses of parathion it was considered necessary to examine the possibility of parathion contamination of the fruits resulting from root absorption. Fruit was taken from plants grown in 12-inch pots and watered with 500 ml. of 0.08 per cent. parathion solution. It was necessary to use a proprietary product containing 20 per cent. of technical parathion since adequate supplies of pure parathion were not available for these experiments. Plants in pots untreated with parathion were used as controls.

Cucumber fruits were removed from the treated and untreated plants and analysed by macerating and extracting with benzene. To macerated fruit from an untreated plant an amount of parathion equivalent to 0.7 p.p.m. was added and on analysis over 90 per cent. recovery was obtained.

The results obtained with the fruits from the experimental plants on two occasions were:—

Treated plants	0.04 p.p.m.
Untreated plants	0.03 p.p.m.
Treated plants	0.02 p.p.m.
Untreated plants	0.02 p.p.m.

Further parathion at double the original rate (500 ml. of 0.16 per cent. per pot) was added to the pots previously treated with parathion and more cucumber fruits from treated and untreated plants were examined as before with the following results:—

Treated	< 0.01 p.p.m.
Untreated	0 p.p.m.

These results are near the limit of sensitivity of the method of analysis employed and with the equipment then available but are qualitatively negative in all cases. They indicate that parathion is not translocated through the root system of cucumbers to growing cucumber fruits in significant amounts. Consequently the use of parathion to control pests in cucumber beds, which would present much smaller quantities of parathion to the plants than were available to plants in these tests, appears to be non-hazardous to consumers of cucumbers grown in treated beds.

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(b) Parathion deposits on Foliage

Little is known about the extent and distribution of the deposits of parathion resulting from its application in "smokes" or as aerosols generated by different types of equipment. Furthermore, very little is known about the nature and extent of the possible risks involved in handling glasshouse plants after treatment with parathion. The provision of a period of several days between the application of parathion and the resumption of normal cultural operations which necessitate considerable handling of the plants, is frequently most inconvenient and, at times, impractical. Investigations of the extent of contamination of the hands through handling plants treated with parathion have been commenced. The method employed has been to determine the amount of parathion picked up on thin cotton gloves by persons undertaking standard cultural procedures for known periods with plants treated with parathion. The amounts of deposits on the foliage and fruits have also been determined.

Full results of this work will be published when the investigations are completed.

V. CHEMICAL INVESTIGATIONS

I. UREA-FORMALDEHYDE REACTION PRODUCTS AS NITROGENOUS FERTILIZERS

By G. W. WINSOR and M. I. E. LONG

In recent years considerable attention has been given to the development of *slow-acting* nitrogenous fertilizers which will ensure a steady supply of inorganic nitrogen in the soil over long periods of plant growth. Interest in such materials has been stimulated by the knowledge that established organic materials such as hoof and horn are by no means as *slow-acting* as was sometimes thought. The rate of decomposition of natural organic fertilizers in the soil can to some extent be retarded by the use of coarser grades of material; the possibility of developing synthetic *slow-acting* nitrogenous fertilizers remains, however, a fruitful field for investigation.

Following the publication of American research^{1, 2, 3} on the development of urea-formaldehyde products as possible *slow-acting* fertilizers, reference to this type of material was made in the Annual Report for 1950. At the same time a programme of research was started at Cheshunt, the preliminary results of which have already been given.^{4, 5}

The problem of developing a synthetic *slow-acting* nitrogenous fertilizer is by no means a simple one. Over 200 urea-formaldehyde products have already been prepared at Cheshunt, including materials of widely different solubility in water and ease of decomposition in the soil. In the course of this work it has been found possible to produce urea-formaldehyde products having rates of decomposition in the soil very similar to that of finely ground hoof and horn. The aim of the present investigation is, however, to produce *slower acting* fertilizers than those at present available; in no case has the required combination of relatively *slow* mineralization of nitrogen and high ultimate availability in the soil as yet been found.

The range of experimental conditions under which urea-formaldehyde products can be prepared is very wide. Thus the methods of preparation recently patented include reaction under highly acid conditions⁶ (pH 0.9–1.7), and also under alkaline conditions (pH 9) followed by a brief acid treatment.⁷ In view of the many alternatives present it is hardly surprising that, quite apart from any other considerations, manufacturers interested in the development of urea-formaldehyde materials as nitrogenous fertilizers have apparently concentrated their attention on research rather than production. A recent American survey⁸ shows the firm of Du Pont to be prominent in research and development in this field, and some reference has already been made to a product named "Uramite",⁹ containing 38 per cent. nitrogen, three-quarters of which is in slowly available form. The only American firm at present marketing a urea-formaldehyde fertilizer, as distinct from plastic wastes, is stated⁸ to be the Warwick Chemical Co. Trials of a fertilizer made in Florida from wood waste combined with urea and formaldehyde to give a polymerised product containing 20 per cent. nitrogen are referred to in the Annual Report of the Florida Agricultural Experiment Stations for 1951.¹⁰

One of the problems which hampers investigation of urea-formaldehyde products is that of assessing their value as nitrogenous fertilizers; no rapid chemical or physical tests have as yet proved adequate for this purpose. Measurements of the rate of decomposition of the samples in the soil thus remains the most satisfactory method for their evaluation in the laboratory. With materials intended as a *slow-acting* fertilizer this is necessarily a time-consuming procedure.

The aim of experimental work now in progress at Cheshunt is to prepare urea-formaldehyde products in which the properties of *slow* liberation of inorganic nitrogen and high ultimate availability in the soil are combined. The main difficulty encountered is to retard the initial rate of decomposition of the materials in the soil without rendering part of the nitrogen so inert as to be virtually unavailable. It would seem that the rate and ultimate extent of decomposition of urea-formaldehyde materials in the soil are rather closely associated, high availability of nitrogen as yet being found only in materials which decompose too rapidly in the soil to be of great practical value.

The preparation and testing of urea-formaldehyde products is being continued and an account of the experimental work will be given in a subsequent Report.

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2. STEAM STERILIZATION STUDIES

By J. N. DAVIES

Previous reports have, in general, dealt with chemical changes in commercially steamed glasshouse soils *in situ*. Commercial steaming is a costly procedure involving the handling of large quantities of soil. It is thus unsuited to the study of the effects of partial sterilization in a wide range of soil types under differing conditions. The need for a simple means of partially sterilizing soil in the laboratory led to the investigation described below. Attempts to simulate commercial steaming in the laboratory by passing steam from a low pressure source into soil via a grid of perforated metal tubing were disappointing. The soil tended to become excessively wet and uneven heating was experienced. More satisfactory results were obtained by partially sterilizing soil in an autoclave. In the experimental work which follows, except where otherwise stated, flasks of soil were heated in an autoclave until a pressure of 10 lb./sq. in. was attained. The autoclave was then allowed to cool, and opened as soon as atmospheric pressure was restored, the whole process taking 20 minutes. Ammonia production in glasshouse soils partially sterilized in this way is very similar in magnitude to that in the same soil commercially steamed *in situ*. In addition the use of this method enables the soil to be incubated undisturbed before analysis and reduces contamination risks to a minimum. Before extensive use of this technique was made it was considered desirable to determine the effect of partial sterilization under various conditions on subsequent chemical changes.

The Effect of Soil Moisture Content

Typical results are given here for a glasshouse soil which had been steamed many times previously. A quantity of soil was spread out in a thin layer and allowed to dry over a period of 24 hours, the final moisture content being 7 per cent. Some samples of the soil were autoclaved at this moisture content while other samples were adjusted to moisture contents of 14 and 21 per cent. by the addition of water before autoclaving. On cooling the samples were incubated at 23.5° C. and analyses for ammonia and nitrate nitrogen were made at intervals. The results for ammonia are given in Table I.

TABLE I
AMMONIA PRODUCTION (P.P.M. $\text{NH}_3\text{-N}$) IN A GLASSHOUSE SOIL AFTER
AUTOCLAVING AT DIFFERENT MOISTURE CONTENTS

Time in Days	Initial Moisture Content, %		
	7	14	21
1	1.4	2.8	4.6
8	8.8	31.7	39.1
16	5.9	29.6	39.7
22	6.0	28.9	40.8
29	6.8	26.9	42.1
36	7.2	29.8	46.7

Maximum ammonia nitrogen values were reached very rapidly after steaming in the samples autoclaved at moisture contents of 14 and 21 per cent., and it can be seen that the higher the soil moisture content, the more ammonia was produced during incubation. In the soil autoclaved at 7 per cent. moisture only a small amount of ammonia was produced. The nitrate contents are not shown since they remained substantially constant throughout.

Similar results to the above were obtained with another glasshouse soil and with a maiden soil which had never been steamed before.

It is apparent from these results that the soil moisture content influences ammonification after

steaming. Little or no ammonia production was observed in soils steamed and maintained in an air-dry condition. With increasing soil moisture content, however, the ammonia produced after steaming was also found to increase. These results are in agreement with those reported by other workers. Walker & Thompson³ conclude that "... it seems likely that steaming soils at high moisture contents will bring about the production of more ammonia than will steaming at lower moisture levels. On relatively poorer soils the effect is not so marked." Simpson & Newton² found that autoclaving soils in an air-dry condition resulted in smaller increases in ammonia than did autoclaving in the moist state.

The Effect of Pressure and Period of Autoclaving on Ammonia Production

Chemical analyses of the soils used in a study of the effect of different autoclaving conditions on subsequent ammonia and nitrate production are given in Table II.

TABLE II

Soil	% Total Nitrogen	% Organic Carbon	% Potash (K_2O)*	% Phosphate (P_2O_5)*	% Total Carbonate (as $CaCO_3$)	pH	M.E.† %
A	0.296	2.50	0.072	0.393	0.83	7.36	24.56
B	0.330	3.07	0.131	0.398	1.74	7.33	24.19
C	0.510	4.55	0.047	0.006	0.37	6.81	28.42
D	0.370	3.52	0.037	—	—	4.38	31.60
E	0.450	3.38	0.050	0.005	—	5.13	33.38

* Soluble in 0.5-N acetic acid. † Moisture equivalent (Bouyoucos¹).

Soils A and B were glasshouse soils which had been steamed many times previously, while soils C, D, and E were maiden loams which had never been steamed before. Soil samples (100-g.) at a moisture content corresponding to 90 per cent. of the moisture equivalent were weighed into 250-ml. conical flasks, which were then plugged with cotton-wool and autoclaved under the various conditions described below. Samples from each treatment were analysed for ammonia- and nitrate-nitrogen immediately the soils were cold, and also after incubation for 7, 21, and 42 days at 23.5° C. All results given are mean values for duplicate determinations.

The Effect of Different Periods in the Autoclave at Constant Pressure

Soils A and B were autoclaved at a pressure of 10 lb./sq. in. for each of the following times: 10, 20, 40, 80, and 120 minutes, and soils D and E for 10, 20, 40, 60, and 120 minutes. The time taken to reach the stated pressure after closing the autoclave valve, and also to return to atmospheric pressure at the end of the treatments, was standardised at 5 minutes in each case.

Ammonia values for the four soils are shown in Table III. The concentrations of ammonia-nitrogen found in the soils immediately after steaming for different periods are given in Table III as the first line of data for each soil (incubation period = 0). These values represent the ammonia formed by thermal decomposition in the autoclave. The ammonia thus produced increased with the period of steaming in all four soils, the effect being particularly marked in the maiden soils D and E.

Comparison of these initial values with those obtained after 7, 21, and 42 days shows considerable ammonification on subsequent incubation of glasshouse soils A and B after all periods of autoclaving. The ammonia produced by biological activity during incubation of soils A and B are shown in Figs. 1A and 1B respectively. Maximum ammonia production in soil A occurred after the soil had been autoclaved for 80 minutes, but differences between the treatments at any one incubation period were not great. In soil B, ammonia production on incubation was very similar after all periods of steaming. Thus it will be seen from Fig. 1B that ammonifying organisms were almost as active in soil autoclaved for 120 minutes as in that autoclaved for only 10 minutes. In contrast, subsequent ammonification in the maiden soils D and E was completely suppressed by periods of 20 minutes or more in the autoclave, and was markedly delayed even by steaming for 10 minutes.

It is clear from the results that under these conditions it was very difficult to suppress ammonification in the glasshouse soils. In the more acid soils, however, ammonification was suppressed by treatments of 20 minutes or longer, and even autoclaving for 10 minutes at a pressure of 10 lb./sq. in. was sufficient to cause a considerable lag before ammonification became active.

TABLE III
AMMONIA PRODUCTION (P.P.M. $\text{NH}_3\text{-N}$) IN SOILS A, B, D, AND E AFTER AUTOCLAVING AT A
PRESSURE OF 10 LB./SQ. IN. FOR DIFFERENT TIMES

Soil	Incubation Period in Days	Control. Not Autoclaved	Period of Autoclaving in Minutes				
			10	20	40	80	120
A	0	1.2	3.6	3.6	4.8	8.5	10.8
	7	0.5	16.6	17.6	19.5	22.3	22.8
	21	0.3	19.6	20.9	22.8	28.2	28.7
	42	1.0	23.0	24.1	26.5	34.1	34.8
B	0	1.5	4.7	5.1	6.6	10.6	16.4
	7	1.3	13.9	13.8	17.1	19.2	24.2
	21	1.1	17.7	19.0	20.3	23.5	29.1
	42	0.8	21.8	23.4	25.1	28.8	33.6
			Period of Autoclaving in Minutes				
			10	20	40	60	120
D	0	24.4	27.7	30.1	36.9	40.8	55.2
	7	23.8	27.7	30.4	40.7	41.9	52.9
	21	26.7	27.4	30.2	40.6	42.1	56.4
	42	24.4	48.5	30.7	39.9	41.4	54.6
E	0	2.4	6.4	10.0	15.9	20.1	31.3
	7	2.1	8.9	10.6	16.3	17.8	32.4
	21	2.4	21.0	10.1	15.3	20.8	30.8
	42	5.3	45.6	11.0	16.4	19.8	31.9

Nitrification was suppressed by all the treatments, whereas in the control samples which were not autoclaved 8.5, 14.8, 14.3 and 38.2 p.p.m. nitrate-nitrogen accumulated in soils A, B, D, and E respectively after incubation for 42 days.

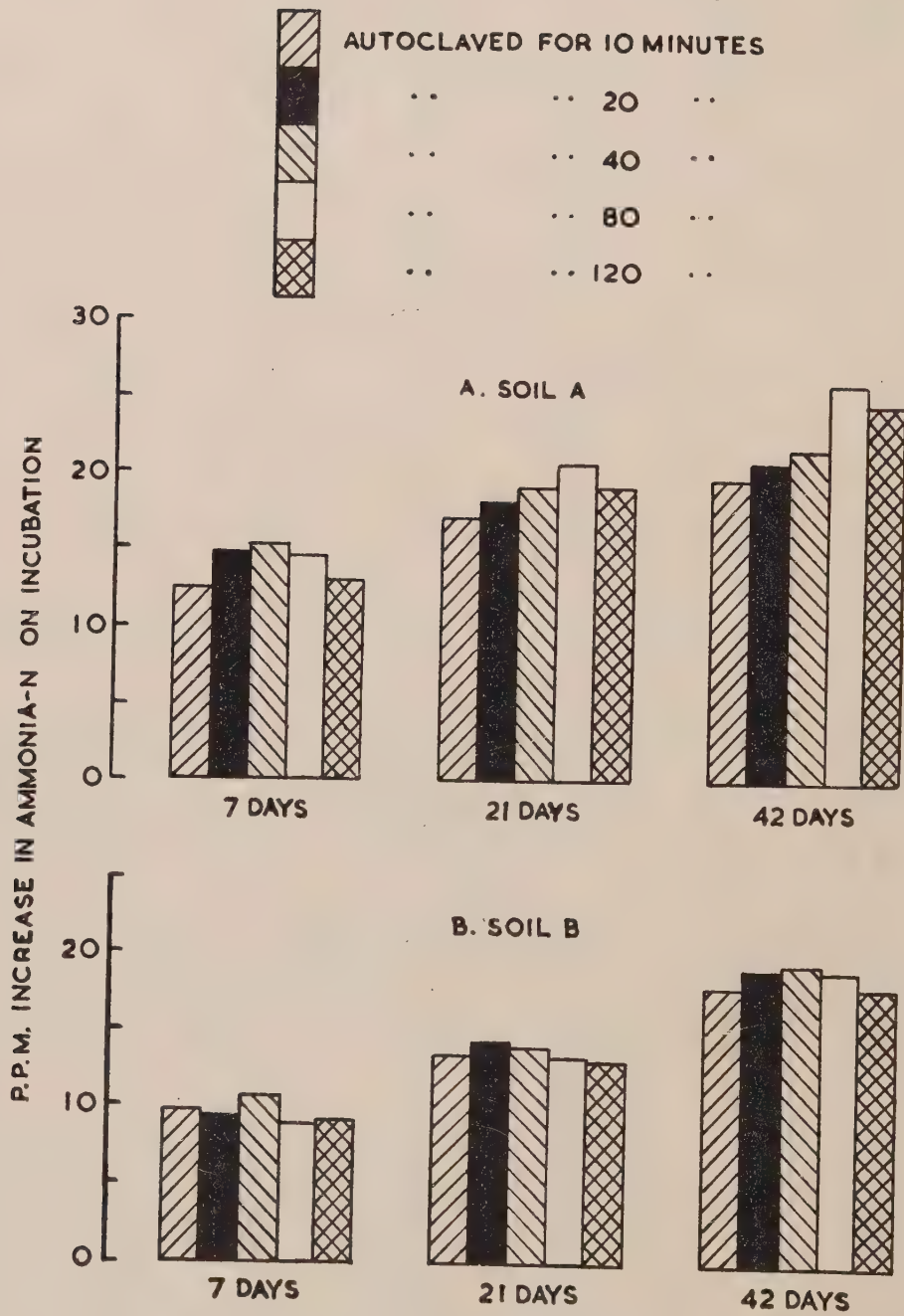
The Effect of Different Pressures in the Autoclave

Samples of soils A, B, C, and E were steamed in the autoclave for 15 minutes at 0 (i.e. with the valve open), 5, 10, 20, and 30 lb./sq. in pressure. The time taken to reach the stated pressures, and also to return to atmospheric pressure, was standardised at 5 minutes in each case. The samples were thus in the autoclave for a total time of 25 minutes.

Analyses for ammonia-nitrogen in the four soils for the different treatments and incubation periods are shown in Table IV.

TABLE IV
AMMONIA PRODUCTION (P.P.M. $\text{NH}_3\text{-N}$) IN SOILS A, B, C, AND E AFTER AUTOCLAVING FOR
15 MINUTES AT DIFFERENT PRESSURES

Soil	Incubation Period in Days	Control. Not Autoclaved	Autoclave Pressure, lb./sq. in.				
			0	5	10	20	30
A	0	0.5	2.4	3.0	4.2	7.6	13.5
	7	0.6	15.6	17.3	19.0	12.7	13.8
	21	0.6	21.1	22.1	25.6	18.2	14.9
	42	2.2	26.4	26.5	29.3	22.3	15.6
B	0	7.7	9.3	9.4	10.6	14.0	18.2
	7	1.0	28.1	27.8	29.5	27.4	19.7
	21	1.0	32.0	32.6	35.3	38.4	25.8
	42	1.4	35.0	35.8	39.0	42.5	32.5
C	0	2.5	6.1	8.2	9.6	15.6	23.7
	7	2.8	86.8	77.8	60.0	14.3	23.4
	21	3.0	129.7	125.9	111.8	18.0	26.0
	42	0.9	139.8	142.9	145.3	18.9	24.8
E	0	7.3	10.1	11.3	12.4	20.2	26.2
	7	9.1	90.7	89.5	10.4	22.2	28.4
	21	9.3	256.8	256.6	28.3	20.5	28.0
	42	9.1	348.7	383.6	44.0	24.5	30.7



Figs. 1A and 1B

Ammonia produced by biological activity in (A) soil A and (B) soil B during incubation for 7, 21, and 42 days after autoclaving for various times at a pressure of 10 lb./sq. in.

It will be seen that as the pressure in the autoclave was increased, increasing amounts of ammonia were released as an immediate result of the treatments. These values may be taken as a direct measure of the thermal decomposition of the nitrogenous compounds in the soil. The results are shown more clearly in Fig. 2, in which the ammonia produced in the four soils has been plotted against the autoclave pressure.

In all four soils, autoclaving at a pressure of 0 or 5 lb./sq. in. for 15 minutes was followed by increased ammonia production on incubation. The amount of ammonia produced in any individual soil in a given incubation period was, in general, similar after both treatments. After autoclaving at a pressure of 10 lb./sq. in. ammonia production in the two glasshouse soils A and B was only slightly greater than after the treatments at 0 and 5 lb. In the maiden soil C there was an initial lag in ammonia production following the treatment at 10 lb., but after incubation for six weeks the ammonia content was similar to that in treatments at 0 and 5 lb. pressure. In contrast, ammonification was markedly retarded in the acid soil E after autoclaving at 10 lb.

The results for treatments at 20 and 30 lb./sq. in. show that in soils C and E ammonification was almost entirely suppressed, there being little difference between the ammonia content immediately after autoclaving and that after incubation. In the glasshouse soils, on the other hand, ammonification was not completely suppressed by autoclaving at a pressure of 20 lb./sq. in. but only retarded. Ammonification in soil B was not, in fact, entirely suppressed even after autoclaving for 15 minutes at a pressure of 30 lb./sq. in.

These results are shown to better advantage in Fig. 3, where the ammonia formed during incubation for 21 days is depicted for the different pressures. Diagrams for the 7 and 42 day incubation periods are not shown since they are of a similar pattern.

In all the soils nitrification was inhibited by steaming under all conditions, and in the case of soil E there was a decrease in nitrate concentration on incubation. In the unsteamed control samples, 7.6, 35.0, 24.7, and 58.4 p.p.m. nitrate-nitrogen accumulated in soils A, B, C, and E respectively during incubation for 42 days.

Discussion

The increased amounts of ammonia found in soils autoclaved for different times at one pressure, or at different pressures for the same time, may be attributed to two distinct causes, namely, the immediate effect of heat on the soil organic matter, and subsequent changes resulting from increased microbial activity. In all the soils examined either increasing the time of steaming in the autoclave or increasing the pressure resulted in increased formation of ammonia as an immediate result of the treatment. Larger increases were observed in the maiden soils which had never been steamed previously than in the glasshouse soils which had been steamed many times before. Thus, for example, in the glasshouse soils the differences in ammonia produced after autoclaving for 10 or 40 minutes at 10 lb./sq. in. were relatively small, but in the maiden soils over twice as much ammonia resulted from the longer treatment. Increasing the autoclave pressure also caused marked increases in the amounts of ammonia produced as an immediate result of the treatment in the maiden soils, whereas in the glasshouse soils the increases were not so pronounced. Simpson & Newton found that autoclaving soil at a pressure of 15 lb./sq. in. produced less ammonia than at 12 lb. They were, however, investigating minimum sterilization requirements of soils, the minimum period at 15 lb. being markedly shorter than at 12 lb./sq. in.²

The effect of the various treatments on subsequent ammonia production differed with the various soils. Ammonification in the glasshouse soils was not greatly different after autoclaving for 10 minutes at a pressure of 10 lb./sq. in. than after treatment for 120 minutes. Autoclaving the maiden soils for 20 minutes or longer, however, suppressed ammonification completely. Similar results were produced by 15 minutes treatment at 20 lb. pressure. In the glasshouse soils ammonification was only retarded by the higher pressure treatments and not suppressed.

Walker & Thompson³ found that in two soils with a pH of 6 ammonia production was not greatly different after steaming for periods ranging from 5 to 30 minutes at 212° F. After steaming for an hour, however, they observed a lag in ammonia production for the first week after the treatment, and ammonia concentrations some seven or eight weeks later were lower than in the soil steamed for shorter periods. In contrast to the present investigation they steamed fairly large quantities of soil, and as Simpson & Newton have shown, the length of treatment required to attain sterility increases with the weight and depth of the sample.²

It appears from these results that, if the absence of ammonia production on incubation is taken as a criterion of sterility, the glasshouse soils which have been steamed many times previously are much more difficult to sterilize completely than are the more acid maiden soils which have never been steamed before. In general, the lower the soil pH the lower was the pressure, or the shorter

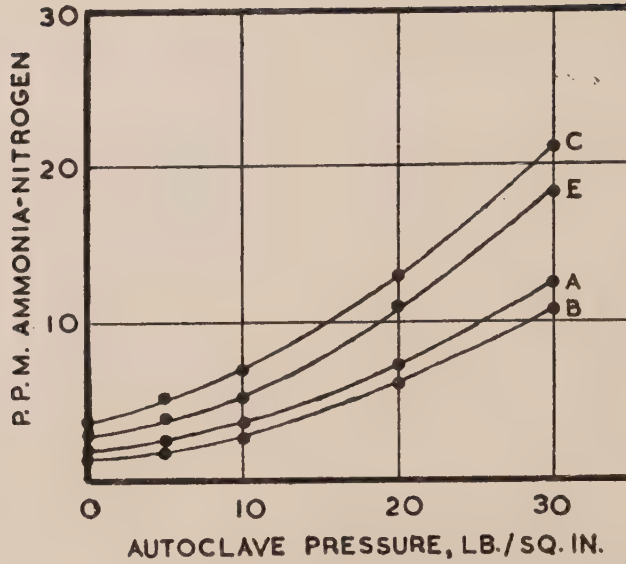


Fig. 2

Ammonia produced in soils A, B, C, and E as an immediate result of autoclaving for 15 minutes at various pressures.

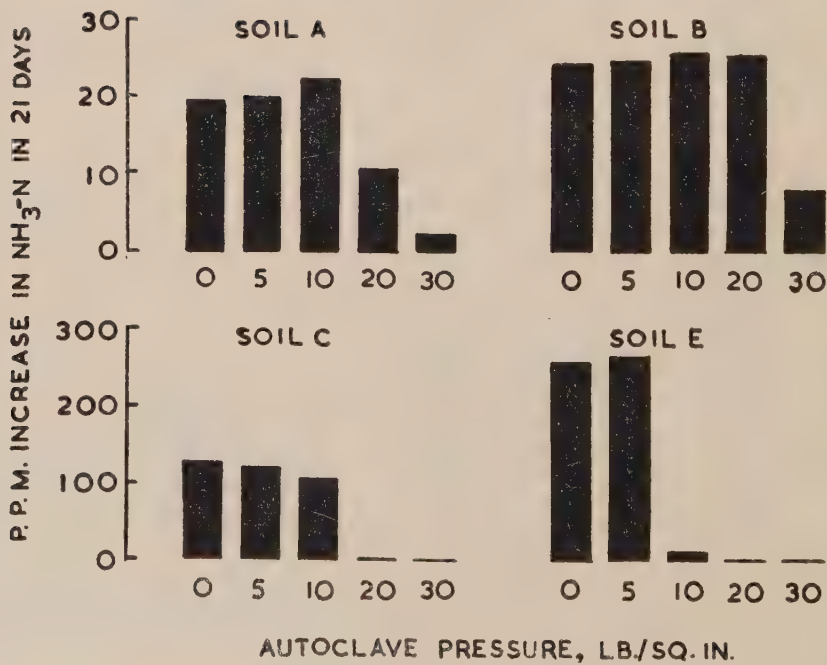


Fig. 3

Ammonia produced as a result of biological activity in glasshouse soils A and B, and maiden soils C and E, on incubation for 21 days after autoclaving for 15 minutes at various steam pressures.

was the time in the autoclave, required to sterilize the soil. It is also apparent that considerable variations in time and pressure are permissible when autoclaving glasshouse soils without affecting subsequent ammonia production to any extent. When more acid soils are partially sterilized in this manner, however, the conditions are much more critical if complete suppression of ammonification is not to result.

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3. THE EFFECT OF SOME ACUTE MINERAL DEFICIENCIES ON PLANT GROWTH

By J. H. L. MESSING

(a) Carnations

To confirm previous observations on mineral deficiencies, and also to extend them to include a fast-growing variety, experiments were made with the variety William Sim. Using the experimental technique previously described, William Sim reacted in much the same way as Spectrum,^{1,2} and no detailed description of the results is necessary.

In the course of these experiments an interesting response to boron deficiency was found; the axillary shoots split the leaf at its base and grew through the split as shown in Plate 1A.

Similar effects had previously been encountered with both White Maytime (Plate 1B) and Spectrum, but the results were not at the time considered adequate to justify description without further confirmation. The effects shown in Plate 1, A and B, are normally preceded by chlorosis of the young leaves, as previously described.

It is of interest that symptoms similar to those shown in Plate 1 were also found on plants grown on a semi-commercial scale in beds of aggregate fed with nutrient solutions. Observations were made on two varieties, William Sim and White Maytime, grown at a high level of nitrogen. Under these conditions William Sim in particular showed considerable stunting, and penetration of the leaf base by axillary shoots was widespread. It was later established that the amount of boron supplied in the nutrient solution, ignoring the undetermined amounts present as impurities in the chemicals and water-supply, was well below what would normally be recommended. On increasing the supply of boron normal growth resulted. Various workers have previously shown that plants grown at a high level of nitrogen have a high requirement for boron^{3, 4, 5}; this conclusion, together with the possibly high boron-requirement of a fast-growing variety such as William Sim, may explain the appearance of deficiency symptoms in this case.

Splitting of the Calyx

In the course of some earlier studies with carnations² certain results were obtained suggesting a possible relationship between splitting of the calyces and iron deficiency. Detailed examination of the results revealed, however, that individual plants in all treatments differed markedly in their tendency to give split calyces. It thus seemed possible that some hereditary factor was operative, and further cuttings were therefore taken from plants with known characteristics in this respect. Lack of space and unfavourable weather conditions during propagation limited the experiment to one variety, namely Spectrum. This experiment is still in progress, but there is already evidence to show that some hereditary factor does indeed play an important role.

Three plants were selected from the experiment of 1952, all grown in nutrient solution from which iron had been omitted. Particulars of these plants were as follows:—

TABLE I
PRODUCTION OF BLOOMS IN 1952 BY THREE CARNATION PLANTS GROWN
IN NUTRIENT SOLUTION CONTAINING NO IRON

Total Number of Blooms Produced	Number of Blooms with Split Calyces	Remarks
18	0	Non-splitting
27	14	Intermediate
31	25	Badly splitting

Cuttings were taken from these plants in November, 1952. All were grown in complete nutrient solution until the beginning of April, after which approximately half the plants received no further

supplies of iron. The results of this experiment, up to the end of 1953, are summarised in the following table:—

TABLE II
PRODUCTION OF BLOOMS IN 1953 BY CARNATIONS RAISED FROM CUTTINGS FROM THE PARENT
PLANTS REFERRED TO IN TABLE I

Characteristics of Parent Plant	Number of Plants Grown		Number of Blooms cut up to Dec. 31st, 1953	
	On complete Nutrient	Without Iron	Total	Split
Non-splitting ...	3	3	49	2
Intermediate ...	1	—	10	7
Badly splitting ...	3	3	23	23

These preliminary results show that the characteristics of the parent plants with regard to splitting of the calyces have been retained in plants subsequently grown from cuttings; the omission of iron from the nutrient solutions has had no apparent effect on the results to date. This aspect of the problem of splitting in carnations may merit further investigation.

(b) Cyclamen

Two varieties of cyclamen were used, these being Giant White and Dark Salmon. The seeds were sown in soil on July 30th, 1952. On October 16th, 1952, the resulting plants were transferred to sand after careful washing of the roots. The containers used were black plastic 5-inch pots, with a drainage hole in the base. Growth in sand culture was started in complete nutrient solution in order to establish the plants, differential treatments being started subsequently. Thus boron and manganese were omitted from February 6th onwards, and all the major elements from March 6th, 1953. The nutrient solutions were applied as necessary, varying from once every three days in the early stages to three times a day during summer when the plants were larger.

The form of the deficiency symptoms was essentially similar in the two varieties, but Giant White reacted more quickly and was more affected by the omission of potassium, calcium, magnesium and boron. Unfortunately it was not possible to study the effect of the various deficiencies upon flowering within the period of this experiment, which was terminated at the end of July.

No Nitrogen

The development of new leaves ceased. Those already formed remained small and lost colour. The oldest leaves turned yellow and died. The few remaining leaves were pale green, but corms survived until the end of the experiment. The corms were small but healthy. The root system was white, healthy and well developed. On returning to a complete nutrient solution resumption of growth followed immediately.

No Phosphorus

The leaves produced were small, dark green in colour, and having a dull appearance. The old leaves turned dark brown and died. The corms remained small.

No Sulphur

The symptoms were very similar to those of nitrogen deficiency, but developed more slowly. The leaves were more plentiful but smaller; they were also noticeably stiffer in texture, though this characteristic had largely disappeared by the end of the experiment.

No Potassium

The size of the leaves was affected at an early stage, these being small though at least as numerous as those on the control plants. It was not until May that the rate of formation of new leaves was reduced. Characteristic symptoms of potassium deficiency were first noted in the second half of June.

Small necrotic patches appeared on the edges of some leaves, enlarging rapidly into semi-circular areas, until eventually the whole leaf died within two to four days. On some leaves the necrosis started at several points along the leaf edge, while in other cases the tips were first affected. At first the development of necrotic areas was confined to two or three leaves per plant at any one time; two weeks later, however, the same symptoms developed suddenly on every leaf, and all died

within a few days. When complete nutrient solution was given at this late stage to half the plants some new leaves started growing slowly after a few weeks; no new growth developed in the absence of potassium.

No Calcium

The omission of calcium from the nutrient solution resulted in small, stunted plants. In May small light coloured necrotic spots appeared on almost every leaf, and rapid death of all the foliage followed. The roots were brown, dying back from the tips.

No Magnesium

Apart from slower growth there were no noticeable symptoms of magnesium deficiency until June. At this stage the leaves became paler, and necrotic spots developed all round their edges. These necrotic patches increased in size, in some cases merging together along the leaf edge, and slowly spread inwards between the veins. The leaves turned bright yellow, and the entire foliage died by the end of June. Giant White responded more rapidly to magnesium deficiency than did Dark Salmon.

No Boron

The effects of boron deficiency were noted early in April, some of the leaves developing uneven yellow patches. This yellowing of the leaves started and was most pronounced close to the petioles and along the veins. The yellow areas soon became covered with necrotic spots, and early death of the leaves followed. As with potassium deficiency, only a few leaves were at first affected at any one time, and slow growth continued. After three to four weeks, however, the symptoms suddenly became more acute and spread to almost every leaf. Death of the whole foliage followed.

When complete nutrient solution was again given the plants made a rapid recovery. As with calcium deficiency, the roots became brown and died back from the tips.

No Manganese

No significant response to the omission of manganese from the nutrient solution was found in this experiment.

(c) Stocks

Seeds of variety Queen of the Belgians were sown on January 30th, 1953. The young plants were transferred to sand culture on March 7th and established in complete nutrient solution; differential treatments were started on March 24th.

No Nitrogen

The leaves were small, light green, and closely packed as a result of slow growth of the stem. The oldest leaves turned yellow and were shed. Flowering was delayed. All the plants in this group produced single flowers, whereas plants receiving complete nutrient solution gave double flowers. A high percentage of single flowers on nitrogen-starved stocks has been reported elsewhere.⁶

No Sulphur

Growth was slow and the leaves noticeably stiff. The young leaves remained small and turned yellow-green in colour. The stem was thin but continued to grow. Light-coloured scars developed on the leaves, and the upper leaves became distorted, these symptoms being very similar to those already described on carnations.² The late appearance and slow development of the flowers also recalls the effects of sulphur deficiency on carnations. The inflorescence was more spread than in any other treatment, individual flowers being small.

No Phosphorus

The leaves were small and dark green. Growth was retarded and flowering was later than in the control series.

No Potassium

Growth was retarded. The old leaves turned brownish-green and then almost papery white, dried up and fell off. Flowering occurred at the same time as or even earlier than the control plants.

No Calcium

The first sign was the cessation of growth of the young leaves, followed by the development of a characteristic tip-scorch. The tips turned white and bent upwards almost at a right-angle to the rest of the leaf, just as described earlier for carnations.¹ The next stage was the death of the growing point of the main stem, and subsequent growth of axillary buds. The young leaves on the resulting

side shoots soon exhibited the same symptoms as described for the main shoot, and in due course their growing points also died. The lower leaves on the main stem continued to grow, but eventually developed light coloured necrotic spots all over their upper surface, and became thick and distorted.

No Magnesium

Growth was retarded at an early stage. Typical marginal and interveinal chlorosis appeared on the middle and lower leaves, and quickly spread until all the leaves were affected. Flowering occurred at the same time as those in the "no potassium" series, and the inflorescences were small and short-lived in both cases.

No Boron

Growth was noticeably checked in the sixth week of treatment. This was followed by thickening of the leaves, particularly the younger ones, and later on by their distortion as shown in Plate 2A. Death of the growing point followed, and axillary buds were stimulated into a brief period of growth before their tips also died.

No Manganese

Growth was definitely retarded, but no characteristic symptoms developed on the leaves.

(d) Dahlias

Seed of variety Coltness Gem was sown in soil on March 6th, 1953. The plants were transferred to sand and treatments started on March 24th.

No Nitrogen

Only one pair of true leaves developed, these being small and pale green. After some four to five weeks the leaves partly regained colour and started to grow slowly, suggesting that small amounts of nitrogen had somehow become available. The possibility of contamination of the nutrient solution would seem unlikely as the same solution was used for lettuce and stocks, grown under the same conditions, without any similar effects being noted. These observations were confirmed in a further experiment, using larger plants. A rapid response was obtained at first with typical symptoms of acute nitrogen starvation. After this initial check, however, slow growth was resumed as in the previous experiment. No explanation of these results has as yet been established; the possibility that the plants can assimilate small amounts of atmospheric nitrogen either directly or symbiotically cannot be overlooked. The number of families of flowering plants now known to assimilate atmospheric nitrogen either symbiotically or otherwise has increased considerably in recent years.⁷

No Sulphur

Growth was retarded at an early stage, giving at first an appearance similar to nitrogen starvation. Later the leaves became stiff and curled downwards. Eventually an irregular necrosis developed on the leaves, followed by death of the whole plant.

No Phosphorus

Only limited growth occurred, as was the case with nitrogen and sulphur deficiencies. The leaves were small and dark green. The effect on the old leaves was similar to that produced by lack of phosphorus on some varieties of chrysanthemum,⁸ necrosis starting at the tip of the leaf and progressing along the midrib.

No Potassium

Response to this deficiency was more rapid than with the other species studied. Well defined necrotic spots of irregular shape appeared on the middle leaves, in some cases preceded by mild chlorosis (see Plate 2B). All growth ceased, and death followed. The experiment was repeated with older, better established plants; the same symptoms again developed rapidly, but in this case growth continued for some time after the death of the middle and lower leaves.

No Calcium

Growth was severely checked, with dark green foliage similar in colour to that of plants showing phosphate deficiency. In the middle of May the young leaves, while still remaining dark green, developed a blackening of the petioles and midribs. The affected leaves died, and death of the entire plant followed in just over a week.



PLATE 1. BORON DEFICIENCY IN CARNATIONS

A (*left*). Variety William Sim, showing the numerous thin axillary shoots growing through the leaves.

B (*right*). Variety White Maytime, showing an axillary shoot growing through the base of a leaf. Note also the split in the node above.



PLATE II

A (*left*). Boron deficiency in stocks, showing thickened and distorted leaves.

B (*right*). Potassium deficiency in cabbage, showing small chlorotic spots. The leaf on the left is normal when grown in complete nutrient solution.



PLATE 3

A (*above*). The fruit from one truss of a tomato plant deprived of boron at an early stage of growth. A normal fruit is shown for comparison on the right.

B (*below*). Fruit from a plant deprived of boron at a later stage of growth, with a normal fruit on the right.



No Magnesium

Growth was stunted, with marginal chlorosis of the middle leaves as an early symptom. The chlorosis spread inwards between the veins, and eventually all the leaves were affected. Later a well defined brown edge scorch developed, the leaves then being yellow in colour with narrow bands of green remaining only along the main veins.

No Boron and Manganese

No response to either of these treatments was noted up to the end of June, at which time the experiment was discontinued.

(e) Lettuce

Sutton's A.1 variety was used, sown early in March. The young plants were transferred to sand culture on March 24th, and the various treatments started immediately.

No Nitrogen

The leaves remained small and became pale green. The older leaves turned yellow and dried up.

No Sulphur

The symptoms were very similar to those of nitrogen deficiency, though with slightly more growth initially. A characteristic stiffening of the leaves was observed. Practically none of the old leaves died.

No Phosphorus

The leaves were dark green in colour and of dull appearance. When the old leaves died they were much darker brown than in the case of nitrogen deficiency.

As in the case of nitrogen and sulphur deficiencies, an open habit of growth was noted, and no heads were formed.

No Potassium

There was no noticeable response to the treatment within the first three weeks. After this, however, the development of new leaves was arrested, and the older leaves developed marginal scorch, turned yellow and died. Early death of the whole plant resulted.

No Calcium

Dark brown, almost black, spots appeared on the youngest leaves. The growing point died early, and the necrotic spots spread to the next leaves, these in turn dying off in succession.

No Magnesium

Typical marginal and interveinal chlorosis was the first symptom. Growth became slow, and the older leaves developed a marginal scorch. No head was formed.

No Boron

Only limited stunting and some tip scorch of the younger leaves was observed just before the plants reached maturity.

No Manganese

No response to the omission of this element was observed.

(f) Tomatoes

In order to clarify certain points arising in our earlier studies, and also to provide material for demonstration purposes, plants of variety Moneymaker were grown in sand culture. The work involved the use of many plants at various stages of growth, and gave an opportunity for thorough examination of the reactions of this particular variety.

The response to the omission of either nitrogen, phosphorus, magnesium or manganese was typical, and no further description of these deficiencies is warranted. Several points of interest arose in connection with deficiencies of potassium, calcium, boron and sulphur, however, these being referred to under their respective headings.

No Potassium

The first symptom of deficiency was the appearance of dark brown spots, these being distributed

over the surface of the middle and lower leaves but mainly concentrated round the edges. This was followed by the development of light-coloured necrotic areas of varying shapes. The leaves were crinkled, lacking their usual smoothness. Growth was restricted, and rapid yellowing and dying off of the affected leaves followed.

These are the typical symptoms of potassium deficiency as recognised by many workers^{9, 10} though it has been claimed¹⁰ that in the presence of high concentrations of sodium these effects are replaced by an edge scorch, or that they are greatly modified when ammonia-nitrogen is the only available form of this element.⁹ The "no potassium" solution used in the present work contained 90 p.p.m. sodium, and both ammonia and nitrate-nitrogen were present. From our experience we are inclined to think that the symptoms differ somewhat with variety and with the stage of growth at which the deficiency becomes operative. Thus young plants suddenly deprived of potassium invariably produced dark spots on the leaves, whereas more mature plants showed marginal chlorosis developing into scorch. Certain varieties are more prone than others to develop edge-scorch, as is well shown on the experimental plots at Cheshunt from which potassium is withheld. In the latter case small amounts of potassium in the soil are available to the plants initially, but the deficiency gradually becomes more acute, showing the full effect at the time of swelling of the first two trusses.

No Calcium

Here, also, considerable differences were observed in the appearance of plants deprived of calcium at various stages of growth.

In the case of young plants, from which calcium was withheld when bearing three to four true leaves, a slight chlorosis developed on the youngest leaves, followed by a sudden rush of necrotic spots which spread all over them. The growing point and uppermost leaves died. No new growth occurred, but the lower leaves continued to develop, these being stiff and straight. The stem died back slowly.

When calcium was withheld from a young plant which had reached the third flower truss, chlorosis of the top growth was again the first symptom. No spots appeared on the leaves, but the young leaves showed a tendency to flag. The growing point died, and brown spots developed on the upper part of the stem. The fruit, already set on the first truss, was affected by blossom end rot. The latter disorder has been associated with calcium deficiency by many workers.^{11, 12}

In a further trial calcium was withheld from a plant which had reached the fifth truss, with the first two trusses setting. The plant was "stopped" subsequently leaving one leaf above the sixth truss, it being difficult adequately to maintain further growth in the relatively small containers used. No chlorosis developed, the only effects being a tendency to wilt and the onset of blossom end rot.

No Boron

Boron was withheld from different plants at the same three stages of growth as described for calcium deficiency. With plants bearing three to four true leaves a mild chlorosis of the newly developing leaves was followed by death of the growing point. The next leaves down were distorted by curling downwards, and were crinkled. The plant remained in this condition for some time before new growth of axillary shoots occurred. These shoots were thin and under-developed, both size and shape of leaves being affected. Some leaves failed to develop laminae, giving an appearance reminiscent of "whiptail" in cauliflower.

With plants at the third flower truss chlorosis of the upper leaves was again the first sign. The leaves became crinkled, stiff, and curled downwards. The growing point died and the top leaves became orange-yellow in colour and were brittle, breaking off easily when handled. Transverse sections of the petioles revealed a brown discoloration of the conductive tissue. The flowers of the upper trusses abscised, and the fruits already set on the bottom truss developed darkened and dried areas as illustrated on Plate 3A.

When boron was withheld from a plant on which the fifth truss was in flower, the growing point showed little further activity and subsequently died, thus rendering "stopping" unnecessary (compare with "no calcium" treatment). The upper foliage was affected as described in the preceding paragraph. The young fruits on the fifth truss were affected as shown in Plate 3B, but no adverse effects were noted on the lower trusses.

No Sulphur

With young plants the effect was very similar to that caused by nitrogen deficiency, but developed more slowly; the outstanding difference was that the cotyledons were not shed, but remained green until almost the whole plant had turned yellow. In the case of nitrogen deficiency the cotyledons are the first to turn yellow, and are shed.

With more mature plants, however, the symptoms of sulphur deficiency differed considerably from those due to lack of nitrogen. Thus the older leaves remained green and healthy throughout. Elongation of the stem was very slow, and eventually ceased completely. The young leaves did not develop to full size, but became pale green, stiff, and somewhat distorted by rolling up of the edges of the leaflets. This description differs from that given by Nightingale,¹³ but is in close agreement with the symptoms of sulphur deficiency of the tomato and of other species as previously observed at Cheshunt and elsewhere.^{14, 15, 16}

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4. THE DETERMINATION OF POTASSIUM IN SOIL EXTRACTS AND PLANT TISSUE

By D. M. MASSEY and G. W. WINSOR

In routine analyses of soils and plant materials the determination of potassium generally involves the use of laborious and time-consuming procedures. In recent years, however, the flame photometer has attracted considerable attention as a rapid alternative to existing chemical methods for the determination of potassium. In this method a solution containing potassium is atomised and introduced into a non-luminous flame, to which it imparts a characteristic colour. The intensity of the light emitted is measured by means of a photo-cell after passing through an optical filter. After preparation of extracts or solutions of the materials under examination, and calibration of the photometer, the determination is thus a rapid routine procedure.

It is well known, however, that high concentrations of certain other elements can interfere with the method, and before adopting the flame photometer as a standard procedure for routine analysis of plants and soils it was necessary to compare the results with those obtained by other methods.

For the comparison of analytical methods for potassium in soil extracts 18 samples were examined, these including glasshouse and market garden soils and maiden loams. The soils were extracted with N/2 acetic acid and potassium determined in the extracts both with the flame photometer and also gravimetrically as potassium perchlorate. The results from the two methods, expressed on the basis of oven-dried soil, are compared in Fig. 1.

Further experiments were made with 13 samples of plant tissue, including tomato leaves and fruit. The plant materials were ashed, the ash being dissolved in dilute hydrochloric acid and the silica separated. The solutions were used for comparison of the flame photometer with a gravimetric method in which potassium was first isolated as the cobaltinitrite and finally determined as perchlorate. The results, expressed on the basis of oven-dry plant tissue, are shown in Fig. 2.

In both soil extracts and plant materials close agreement was found between the photometric and gravimetric results, the correlation coefficients being 0.987 and 0.988 respectively. The linear regression of the flame photometer values on those obtained by the gravimetric methods is shown in the graphs.

It is concluded that the flame photometer provides a rapid and reliable procedure for the routine determination of potassium in soil extracts and plant materials.

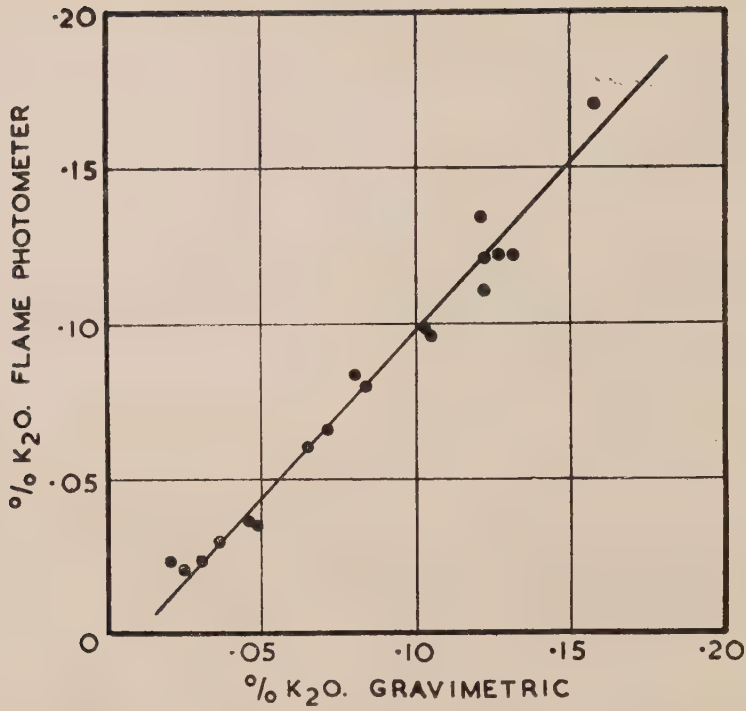


Fig. 1
Correlation between determinations of potassium in soil extracts by gravimetric and photometric methods.

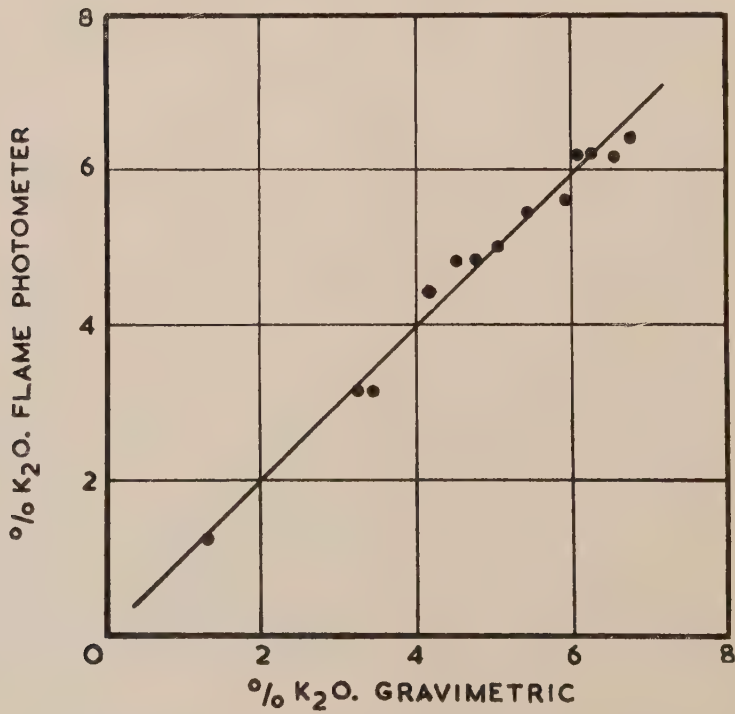


Fig. 2
Correlation between determinations of potassium in plant tissue by gravimetric and photometric methods.

5. SOIL SAMPLING AT THE GLASSHOUSE CROPS RESEARCH INSTITUTE

By G. W. WINSOR, J. N. DAVIES and D. M. MASSEY

A series of soil samples was taken in November, 1953, on the site of the new Research Institute at Toddington. Two blocks of four glasshouses, one consisting of "aeroplane" type and the other of "vinery" type houses, were examined in detail. For the purpose of sampling each house was divided into eight plots, each consisting of a 25-ft. length of border, giving 64 plots in all. Eight borings to a depth of 10 inches were made with an auger in each plot. A further block of four "aeroplane" type houses had to be left unsampled, being partly covered with excavated soil.

The following determinations were made on the soil samples:—

- (1) Organic carbon (Walkley and Black).
- (2) Total nitrogen.
- (3) Phosphate extracted with N/2 acetic acid.
- (4) Potash extracted with N/2 acetic acid.
- (5) Carbonate.
- (6) pH of soil suspensions (water/soil ratio 2.5 : 1).
- (7) Conductivity of soil suspensions (water/soil ratio 2.5 : 1).

Examination of the analytical data for the 64 plots shows considerable uniformity in organic carbon and nitrogen content. The phosphate and potash values are uniformly low throughout, as is the content of water-soluble salts. The carbonate content shows some variability between plots, this also being reflected in the pH values. The range of values obtained is given in Table I.

TABLE I
SUMMARY OF ANALYTICAL RESULTS FOR TOMATO HOUSES (C1-D4)

	Range of Values	Mean
Organic carbon, %	0.80-0.99	0.92
Nitrogen, %	0.117-0.141	0.130
Available phosphate, % ...	0.0002-0.0011	0.0006
" potash, %	0.003-0.007	0.005
Carbonate (as CaCO ₃), % ...	0-0.29	—
pH	5.6-7.6	6.8
pC	3.53-4.05	3.82

TABLE II
ANALYTICAL RESULTS FOR EIGHT GLASSHOUSES (C1-D4), EACH VALUE BEING THE MEAN FOR EIGHT PLOTS

House	C1	C2	C3	C4	D1	D2	D3	D4
Organic carbon, %	0.93	0.94	0.94	0.90	0.90	0.92	0.88	0.93
Nitrogen, %	0.134	0.133	0.132	0.131	0.127	0.134	0.122	0.129
Available phosphate, % ...	0.0005	0.0005	0.0005	0.0006	0.0006	0.0006	0.0005	0.0006
" potash, %	0.004	0.005	0.005	0.005	0.004	0.005	0.004	0.004
pH	6.7	6.3	6.7	6.9	6.9	6.8	7.0	7.1
pC	3.87	3.87	3.80	3.79	3.81	3.81	3.80	3.81

The mean results for each of the eight houses are given in Table II. These average values show considerable uniformity throughout.

The soil in the seven cucumber houses was too hard to permit representative sampling at the time, but analysis of 14 samples gave results very similar to those already reported for the tomato houses. The range of values obtained is shown in Table III.

TABLE III
SUMMARY OF ANALYTICAL RESULTS FOR CUCUMBER HOUSES (A1-A7)

	Range of Values	Mean
Organic carbon, %	0.82-1.07	0.96
Nitrogen, %	0.124-0.153	0.140
Available phosphate, % ...	0.0004-0.0012	0.0007
" potash, %	0.004-0.006	0.005
pH	6.4-7.6	7.2
pC	3.39-3.83	3.66

As previously stated, the ground in one block of four tomato houses (B1-B4) was partially covered with excavated soil. Though little different from the top soil in appearance, the heaped soil was found on analysis to be extremely low in organic matter, and will be removed from the houses before cultivation commences.

VI. INVESTIGATIONS IN PLANT PHYSIOLOGY

I. A FIRST YEAR'S OBSERVATIONS ON THE GROWTH OF ROOTS AND TOPS OF GLASSHOUSE TOMATOES, WITH SPECIAL REFERENCE TO DEVELOPMENT OF THE FRUIT

By E. R. LEONARD

Introduction

Numerous references to tomato roots have appeared intermittently since 1916 in Annual Reports from this Station. They were apparently based on very restricted observations and in most instances no quantitative data were presented.

There appear to have been serious misconceptions on (i) the extent of the root system as grown in glasshouse borders, (ii) its development during the growing season, (iii) the incidence and importance of fungal rotting, and (iv) the reaction of a defective root system on fruit production. There also appear to have been misinterpretations (v) of the failure of response to applications of fertiliser, this having been blamed on defective root development, equally (vi) of the incidence of mineral deficiencies, and (vii) the seasonal uptake of water. Again, (viii) the effects of different environments on the plant, in particular the weather during seedling growth in different years, have been ascribed, without adequate observation, to "lack of balance" in the growth of tops and roots. The practices of (ix) root restriction at the seedling stage and (x) "stopping" during the fruiting period have been based on empirical data. In most of the experimental work yield, i.e. weight of fruit picked per plant or per acre, has been the sole criterion, with earliness and quality as secondary desiderata. This gives a very limited assessment of the plant's growth.

It was therefore thought, in planning a plant physiological programme, that any quantitative information on tomato root growth would be of value; and since growth in glasshouse borders rather than in pots is the general practice, this has been made the first object of study.

It cannot, of course, be accepted as established that the effectiveness of the root system as an absorbing organ is directly proportional to its extent at any time, but determination of this extent and of changes in it may serve as useful checks on hypotheses pending investigations on absorption. Certain observations during watering and percolation experiments may also find an explanation in the trends of root growth now being established and further investigated. Some of the early work mentioned above will be discussed in relation to the new experimental data when these have been presented.

In the Annual Report for 1951 (XXXVII, p. 84) a summary was given of some of the results of the first year's work under the present scheme. Three subsequent years' work have confirmed the trend of growth of the root system during the first half of the growing season, though differences have been noted in the later part of the year.

Technique

It was first necessary to determine the maximum depth to which tomato roots penetrate when grown under commercial conditions in a glasshouse at Cheshunt. The soil has been described as a light loam moderately rich in organic matter (Ann. Rept. XXXII, 1946, 18), overlying yellow Lea Valley gravel at 12 to 14 inches. It is thus well drained (Ann. Rept. XXXIII, 1947, 15). A mechanical analysis was given in the Annual Report for 1923 (Owen, 1924). It had been cultivated under glasshouse tomatoes since 1923 and was steam-sterilized and flooded during the winters of 1949 and 1950.

An advancing trench was dug towards a row of tomato plants across a border in August, and the amount of root determined, by picking out the fragments and measuring them, so that the total length, in successive 4-inch vertical horizons, was obtained. The data will form the subject of a later report. Meanwhile it is sufficient to state that less than 1 per cent. of the total length was found in the layer at 2 ft. 4 in. to 2 ft. 8 in. A glass-sided box and glass-lined trench were therefore made, 2 ft. 8 in. deep and of the maximum length possible, 4 feet, between the two lines of hot-water pipe, across a border of an aeroplane type glasshouse. Potentate seedlings at the usual eight-rough-leaf stage, about 6 in. high, were planted out (March 19th) down the centre of the box and 6 in. from the glass faces of the trench. The total length of root visible against these glass sheets was measured, at weekly intervals, from the first appearance throughout the season. This total

length visible, of course, does not give the total length of the root system, which can only be ascertained by the method noted above, which involves destruction of the plants. It is, however, the simplest method of following the trend in growth of a cross-section of the root system of a plant or row of plants over a period of time. The presence of the glass may be expected to have biased the estimate of the extent of the root system, especially in the downward direction. A disadvantage of this technique is that the measurements are very time-consuming.

Observations were also made of the length of stem and laterals, the number of leaves produced and the number present after "leafing" (removal of lower, yellowing leaves); and the number and condition of the trusses. The weights of the individual fruits were taken when ripe for picking and their position on the plants noted. Temperatures of the soil and air were also taken.

Experimental Results

Since the trends in growth of both the tops and roots of the plants in the box and those against the sides of the trench were closely similar, no distinction is made here in discussing them. This similarity occurred despite the differences between the environment of the two sets of plants. Some of these are obvious whilst others may be less so. The plants in the box were less shaded than those in the border and their roots were in soil whose temperature, due to the proximity of the hot pipes to the bottom of the box, did not have the usual gradient from the surface down, which is present in the border, where heat is received from the sun and pipes at the surface only. Also the soil had been disturbed during excavation from the border and filling into the box (in the same order of horizons) and so was not in the normal state of compaction, and, finally, the glass faces were exposed to the light and showed marked daily cycles of temperature change.

STEM

In Fig. 1 the growth data for the stem, leaves, and roots are given. The increase in stem length (top) is shown to be at an almost constant rate from the time the first measurement was made, at the end of March when about 10 inches high, until the main stem of the first plant (that under the eaves) was stopped, at the end of July, when about 7 feet long. Thereafter, as successive plants were stopped, the curve sloped off to a steady level in August, when all the four plants had been stopped. Measurement of the length of the laterals, the first of which was allowed to develop in mid-May, was not begun until it was evident which of these organs would be allowed to remain permanently. The few measurements made before the laterals, in turn, were stopped in August show that the trend in growth of these organs was of the same type as that of the main stem. Numerous laterals were, of course, produced but "pinched-out" after a short existence, before and after the main stems were stopped.

LEAVES

Fig. 1 also shows (centre) the production of leaves (chain link). Approximately three per week appeared on the main stem throughout the growing season until it was stopped, and there was a similar, relatively steady production on the plants as a whole (chain link and triangles), after the development of the permanent laterals. On the other hand, due to leafing, the number of leaves *present* (continuous line) on the main stem reached a fairly steady level in mid-May and this, due to the production of new leaves being accompanied by removal of the old basal leaves at about the same rate, was maintained until August, whenceforward, with stopping of the main stem and consequent cessation of production, it fell until the end of the season. The number of leaves present on the plant as a whole (continuous line and triangles) reached a peak at the point when all the main stems and laterals were stopped and then showed a rapid decline to a low value, due to leafing on the main stem and laterals.

It thus appears that, under the cultural treatment given and the environment provided, the main "skeleton" of the plant on which leaves and fruit are borne, followed a steady course of development until extension growth reached the physical size limit imposed by the glasshouse and nurseryman's convenience. This occurred despite the changes in the environment. These consisted of (a) increasing day length (from about 12 hours in mid-March to 16½ hours in June, falling to nine in November) and increasing average daily sunshine hours (Fig. 2 top): there was a short period of high sunshine during the third week of April and another during the first three weeks of June; (b) rising air temperatures from April to June and then relatively constant until September, with a steady fall thenceforward (Fig. 3 top). This relatively steady growth independent of the varying aerial environment is possibly commonplace knowledge and the aim of the grower. The cultural treatment included the application of a base dressing and ten top dressings at fortnightly intervals, between May 9th and August 8th. (See Ann. Rpt. XXXVII, Appendix "B", House 7)

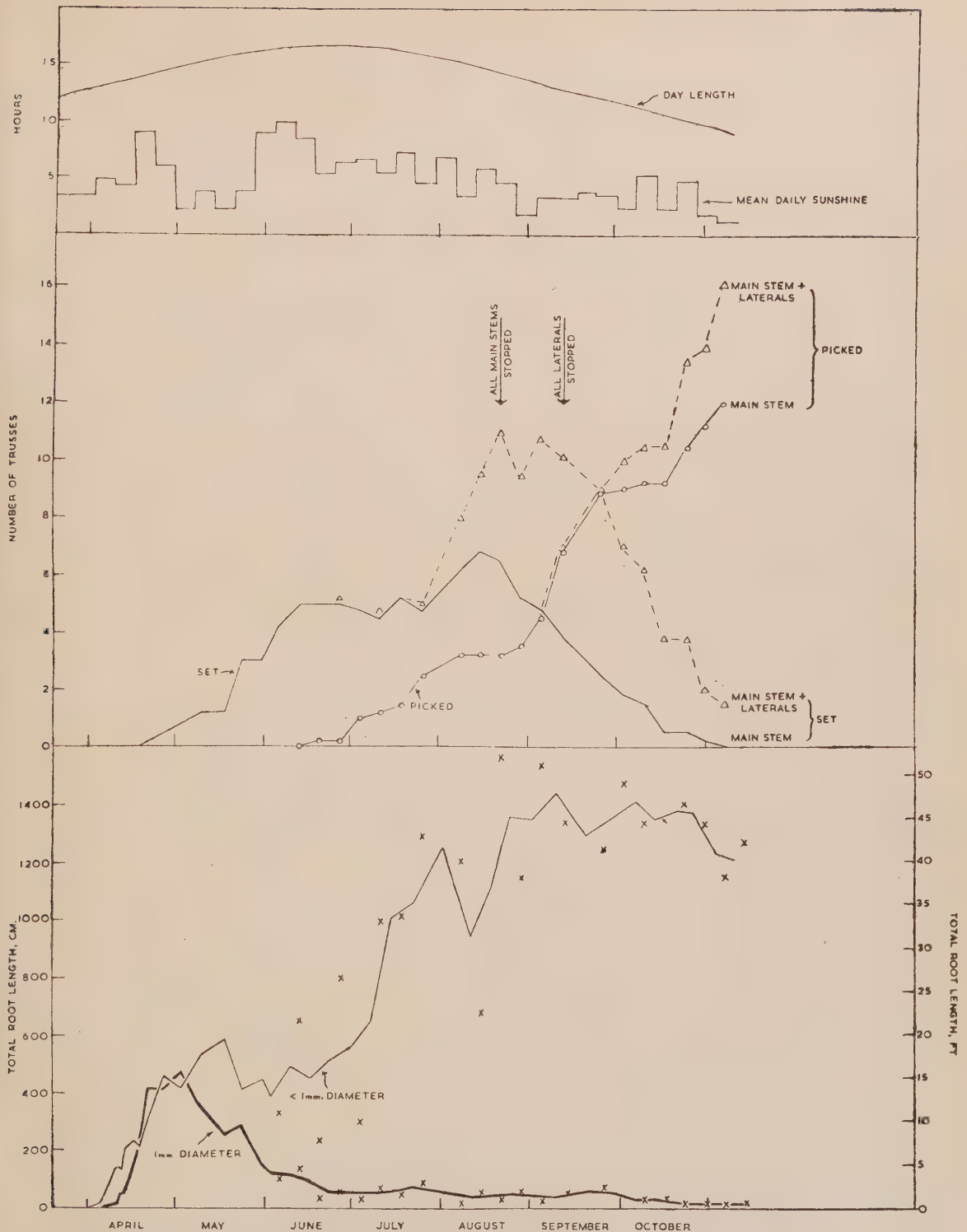


FIG. 2. *Top:* Daylength (hrs. from sunrise to sunset); and mean daily sunshine hours (Campbell—Stokes) on weekly basis.

Centre: Mean number of trusses set on main stem (continuous line) and main stem plus laterals (broken line and triangles) and mean number of trusses picked on main stem (continuous line and circles) and main stem plus laterals (broken line and triangles) of four plants against side of trench. Arrows indicate dates on which all main stems and all laterals were stopped.

Bottom: Total length (cm. and ft.) of roots of the four plants as seen in glass sheet as Fig. 1, of 1 mm. diameter (thick line) and less than 1 mm. diameter (thin line). Crosses indicate observed values from June onwards, running means having been used in the construction of the curve.

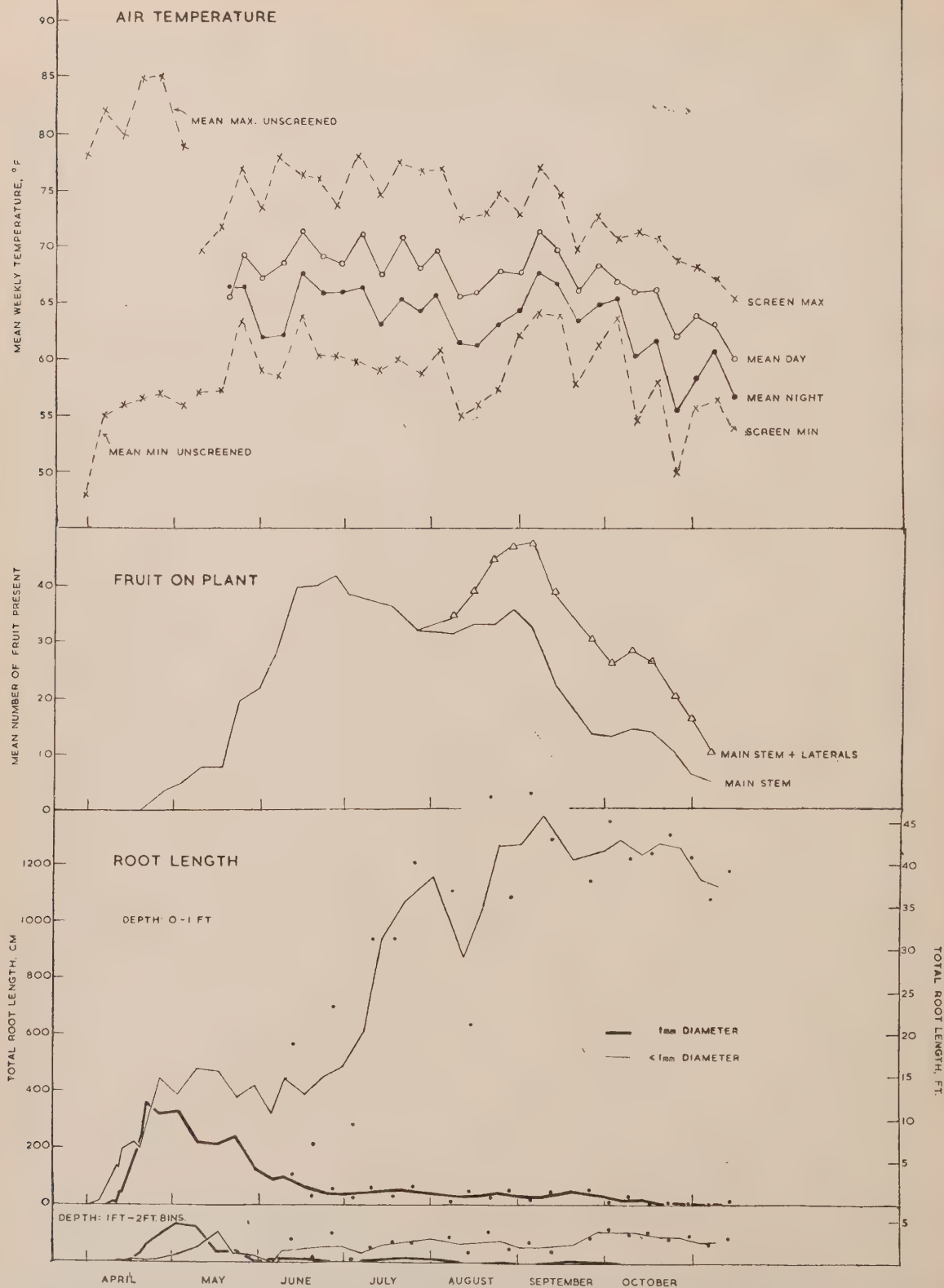


FIG. 3. *Top*: Mean weekly maximum and minimum air temperatures (°F.), March to early May (broken line and crosses) from unscreened Six's thermometer at 7 ft. above ground. From May to November, mean weekly maximum and minimum air temperature (broken lines and crosses) from M.O. type thermometers in louvered screen 4 ft. above ground. Mean day (thin line and open circles) and night (heavy line and closed circles) from thermograph in similar screen.

Centre: Mean number of fruit present on main stem (continuous line) and main stem plus laterals (continuous line and triangles) of four plants against trench.

Bottom: Total length (cm. and ft.) of roots of four plants as seen in glass sheet as Fig. 1, of 1 mm. diameter (thick lines) and less than 1 mm. diameter (thin lines) in upper loam soil and lower gravel. Dots indicate observed values from June onwards, running means having been used in the construction of the curve.

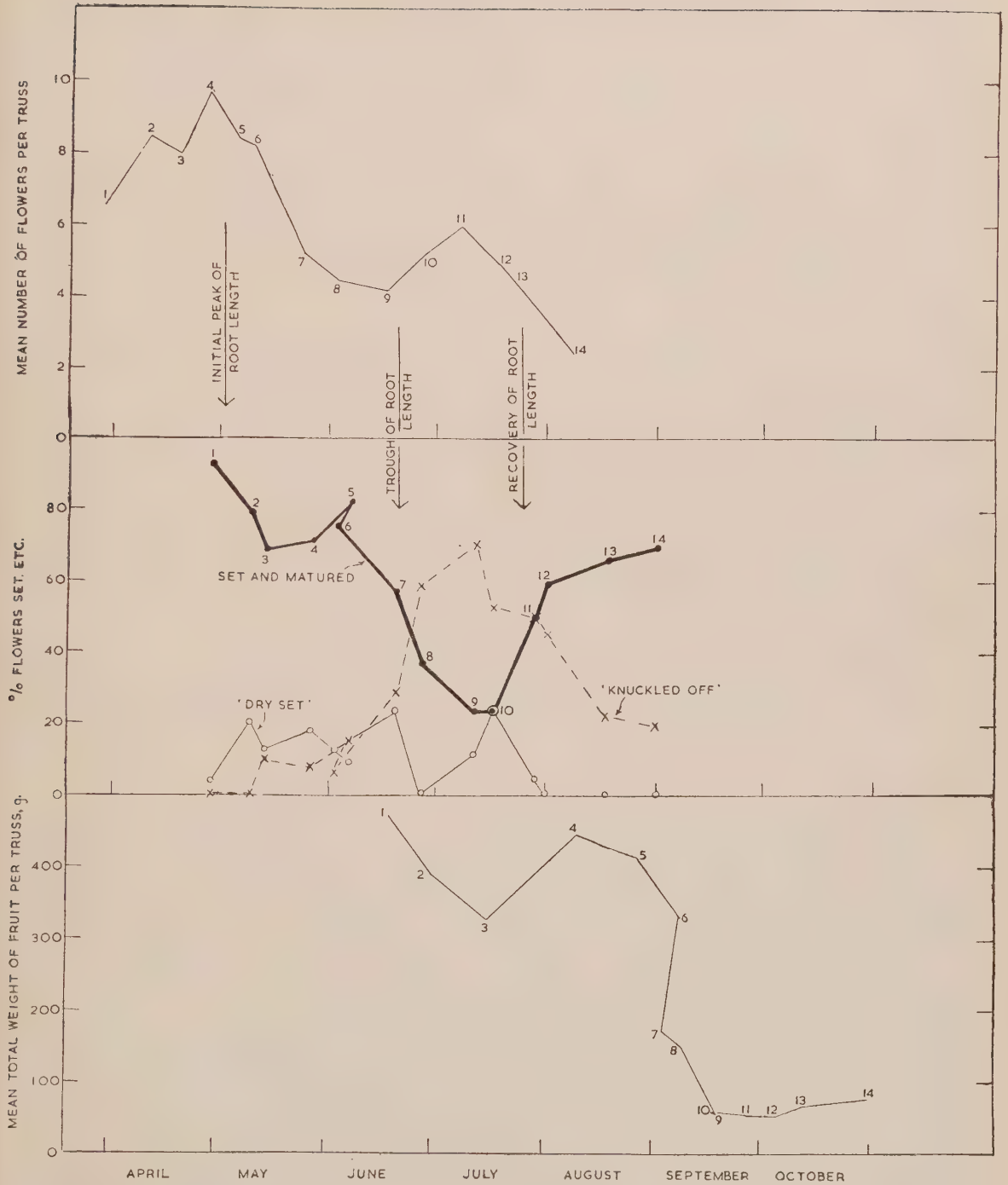


FIG. 4. *Top*: Mean number of flowers per truss in the successive trusses of four plants against trench, entered on mean date on which each truss was first observed. Arrows indicate the times of the successive phases in development of the root system as observed by measurement of the total length visible in the glass panel.

Centre: Fruit set and matured (heavy line and solid circles); "Dry set" (thin line and open circles); and "knuckled off" (broken line and crosses) as mean percentages of number of flowers per truss in successive trusses of the four plants, entered on the mean date of setting.

Bottom: Mean total weight (g.) of fruit picked from successive trusses of the four plants, entered on mean date of picking.

Roots

The trends of growth of the root system, as ascertained from the changes in the total length visible in the glass faces, present what is believed to be a new aspect of the plant's development, and are in marked contrast to the relatively simple growth trend of the aerial organs just described. At the bottom of Fig. 1 the total length of roots from all four plants is given. Roots were first observed in the glass face of the trench at the beginning of April, i.e. a fortnight after planting out, and the increase was at first very rapid. By early May the increase had slowed down and the total length, after reaching a maximum, showed an almost equally rapid decline to a low level at the beginning of June. This rise and fall was also seen in the two glass faces of the box, the data for which are not given here. Due to the better contact of the soil with the glass in the box at all depths, it was possible to observe the trends at the lower levels. The observations showed that the roots reached the bottom of the box, 2 ft. 8 in. deep, 36 days after planting out. Roots were first visible from these plants, which were distant 1 foot from the glass, in the soil at a depth of 8 inches to 1 foot after 20 days, i.e. slightly later than from the plants in the trench which were distant only 6 inches from the glass. There were thus no marked differences in the times of development of the root system at the different depths.

Until early June the trends in growth of both tops and roots of the plants in the box and against the trench were closely similar. For various reasons it was decided to harvest the former at this time. They were 5 feet tall and had produced 34 leaves of which 18 were present, with four trusses setting or set. The first trusses were just about to commence ripening.

Excavation of the soil in successive 4-inch layers adjacent to the glass faces and measurement of the total length of root present gave a close correlation with the length visible in the corresponding areas of glass 4 inches deep. Very roughly one unit of length visible in a 4-inch horizon of the glass face corresponded to 200 to 300 units of root length in the soil at that depth 4 inches inwards from the glass and from 1,000 to 3,000 units in the respective 4-inch horizons as a whole. This suggests that measurement of the length of root visible in the glass gives a reasonable representation of the root system as a whole. But further investigation is desirable.

The further course of the growth of the roots was followed in the plants against the trench. These were at very much the same stage of development at the beginning of June as were the plants in the box.

A marked recovery in total length of roots occurred from mid-June until early August, i.e. when the tops were stopped. The actual observed weekly values are inserted as solid circles at the bottom of Fig. 1, but it is believed that the wide fluctuations these show (especially in the recovery phase) are, in part, due to differences in the alternate observers' criterion of live and dead root, and running means have therefore been used to construct the curve of root length. It must be noted that whereas the early trend, i.e. from March to June, has been repeated in experiments in the two subsequent years, the recovery of root length, though present, was less marked in these years (1952 and 1953).

Subdivision of the total root length into the length of thick (1 mm. diameter) and thin (less than 1 mm. diameter) roots gives a slightly different picture of the trend in root length. This is shown in Fig. 2, bottom. The early rise and fall in root length occurred in both thick and thin roots, the former reaching its maximum and falling slightly earlier than the latter, but from mid-June onwards there was no recovery in the total length of 1 mm. diameter roots, which remained at a relatively steady, low level. The thinner roots, on the other hand, showed the recovery to the new high level in August as described above; so that in the later stages of the plant's development the root system consisted almost exclusively of thin roots. The main skeletal roots from the hypocotyl, or short tap-root, were not visible in the glass sheet at 6 inches from the plants. Running means have again been used to construct the graph from June on, with observed values as crosses.

Fig. 2, centre, shows the number of trusses set (continuous line) and picked (continuous lines and circles) on each date of examination. Setting of the first truss began about the end of April and that of subsequent trusses proceeded at a fairly steady rate until mid-June, when five trusses had set. The first trusses were completely picked by the beginning of July so that the number set on the plants remained approximately constant for a short time (production and picking balancing) with a further rise between the end of July and mid-August, during which period trusses began to set on the laterals (broken line and triangles). A peak number of trusses set on the whole plant was reached at the time when the main stems were stopped, after which, with continued picking, the number fell continuously until the end of the season. Picking of trusses on the main stem proceeded at a steady rate until early August when there was a short delay during which the maximum number of trusses set on the whole plant was reached. Thereafter the number of trusses picked rose continuously until the end of the season.

An interesting observation is the inter-relation in time of the trend in growth of the root system and the trusses. Setting and development of the first trusses are seen to have occurred at the time of the initial peak in development of the roots; the trough of development of thin roots and their subsequent recovery are associated with picking of the lower trusses and the new, sustained high level of development was attained when the main stems and laterals had been stopped.

Whilst the underlying causal mechanism remains a subject for further study, it may be hypothesised that competition of some kind exists between the developing fruit and the root system, which, in order to exploit the available resources of the soil, must be constantly renewed. During periods of strain, as when successive basal trusses are developing, the roots suffer and only recover when the strain is relieved consequent on picking the earliest ripening fruit. It is too early in the investigation to speculate on the various interactions involved but the problem of root development, death and renewal obviously involves consideration of the watering and fertilising programme, just as much as does that of the extension growth of the aerial portions of the plant.

The problem of the distribution in time of the strain on the plant is exemplified in a slightly different way in Fig. 3, centre. This shows the total number of fruit set and developing on successive occasions, derived from the number known to have set per truss (from the final harvest data), plotted against the date of completion of setting of the trusses, from which, on dates after the beginning of July, the number of fruit removed in picking were subtracted. There is seen to have been a steady rise to a peak at the end of June, immediately prior to picking, followed by a slow fall to a shallow trough at the end of July, i.e. when setting on the laterals was beginning and the recovery of root length was nearly complete. There followed a slight rise in the number of fruit present on the main stem, accompanied by the rise in number of those on the laterals, the maximum being attained when the main stem and laterals were stopped, and followed by a fall as more and more trusses were picked.

The bottom of Fig. 3 shows the total root length subdivided into the total lengths of thick and thin root in the two main soil horizons, the light loam from the surface down to 1 ft. 4 in. and the underlying gravel. The early trend, April to early June, was the same in both horizons and both thicknesses of root, i.e. a rise and fall. This indicates that production and subsequent loss of roots occurred in both these subdivisions of the total volume of soil exploited by the root system and at about the same time. The peak of thick root development preceded that of thin root in both horizons, and the peak of both was earlier in the upper layer of soil. A finer subdivision of the data from the box, into layers of soil 4 inches deep, confirmed this. The subsequent recovery in thin root development was considerably more marked in the top soil. The inter-relation of root development with the number of fruit present is seen by comparison with the centre curves of Fig. 3.

FLOWERS AND FRUIT

That there is an interaction between the phases in development of the root system, just described, and the factors contributing to yield is suggested by the data of Fig. 4. Basically yield consists of the number of fruit set per truss $\times$ the average weight of fruit per truss $\times$ the number of trusses. All these factors vary with variety, cultural treatment and environment. A first requisite is the production of flowers. The mean number of flowers per truss in the successive trusses, entered on the date on which each truss was first observed, showed an overall downward trend, Fig. 4, top, with peaks at the fourth and eleventh trusses, and a marked trough in the seventh, eighth, and ninth trusses. The early peak coincided with the initial peak of root length development and the trough at truss nine with the subsequent low level of root length.

The fate of the flowers in the successive trusses is shown in the centre of Fig. 4. The number of flowers which set and matured (heavy line and circles), the number "dry set" (i.e. those in which the ovary does not develop beyond about $\frac{1}{8}$ inch diameter, light line and open circles), and the number "knuckled-off" (broken line and crosses) are expressed as percentages of the total number of flowers per truss, entered on the mean date on which the trusses had set. The bottom trusses, one to six, showed a high percentage set, with low "dry set" and very low "knuckling-off". This setting occurred during the phase of decrease in the root system. The subsequent decline in setting, trusses seven to ten, is reflected in a rise to a peak in the percentage "knuckling-off", with low percentage "dry set". The distal trusses on the main stem, 11 to 14, showed a marked rise in percentage set, with decline in "knuckling-off". The trough of setting occupied the period during which the length of the root system was recovering to the final late high level, which was reached coincident with the recovered fruit set.

Finally the bottom of Fig. 4 shows the total weight of fruit picked from the successive trusses, entered on the mean date of picking. Trusses one to six, which were produced during the period up to the initial peak of root length and developed between then and the trough, ripened and were

picked during the period of the trough, recovery and early stages of the late season level of root development. The other (top) trusses, seven to 11, contributed a very much smaller weight of fruit to the total yield. The mean weight of individual fruit was almost the same as that in the bottom trusses but the number of fruit per truss was very much less. This is a combined result of the production of fewer flowers per truss (Fig. 4, top) and of the lower percentage set (Fig. 4, centre).

Discussion

Only limited conclusions are advisable after this first year's preliminary examination of the growth trends of the tops and roots of glasshouse tomatoes, which had as its chief aim an exploration of the practicability of the glass panel method as a means of following the meristematic and extension activities of roots and of relating these to those of the tops. All cultural treatments were left to the nursery staff, the intention being to observe the effect of these, evolved over many years' practical experience, on the growth of the different constituent plant organs.

An association in time between root and fruit development does not imply a casual relationship, and work is now proceeding on an examination of this aspect. There are, however, numerous indications in past work that such a relationship exists.

Many scattered statements by earlier workers at Cheshunt combine to show that a mid-seasonal check to the tomato plant's development and loss or decrease in activity of the roots had been observed and attempts made to obviate or remedy them. Such are the application of turf or peat as top dressings (Ann. Rept. XVIII, 1932, 10, 17 and 23-24), or planting in trenches subsequently filled up (Ann. Rept. XVIII, 1932, 17; XIX, 1933, 9 and 21; XXI, 1935, 9 and 23-25; XXII, 1936, 11 and 31; XXIII, 1937, 12; XXXVII, 1951, 9 and 14-15).

Lack of fertiliser has been given as a cause for a mid-seasonal reduction in the number of blossoms formed and decrease in extension growth (White, 1938; Ann. Rept. XXIX, 1943, 10 and 16-18; Ann. Rept. XXXIII, 1946, 12-13; Owen, 1945; Ann. Rept. XXI, 1945, 81-83). The mid-seasonal check may also have been the reason for the former practice of stopping tomato plants at the fifth or sixth truss, subsequent growth being by a lateral (Ann. Repts. II, 1916, 11 and 22-23; III, 1917, 13; IV, 1918, 16-17; XIV, 1926, 16; XV, 1929, 81; XXI, 1935, 25; XXII, 1936, 25-29). In 1930 (Ann. Rept. XVI, 1930, 20 and 57) it was stated that as in previous years the heaviest crop was obtained when the plants were grown on without stopping. A relatively high yield was obtained where the plants were stopped at the third and each succeeding second truss, but this result was rendered less significant by variation between replicate plots. In 1931, again (Ann. Rept. XVII, 1931, 10 and 18) plants not stopped at all gave the heaviest crop. There are no references to the practice of stopping after 1936.

Enrichment of a glasshouse atmosphere with carbon dioxide was found to be most beneficial at periods of strain in the life of the plant and in the development and maturation of fruit hanging at these periods (White, 1928). There are two such periods in the life of the tomato plant as grown stopped at the fifth truss. The first of these occurs when the plant has been stopped and is providing side shoots, for the formation of the "top" of the plant and at the same time carries a heavy crop on the bottom trusses. The second period comes towards the end of the season when the plant "is exhausted with the strain of continued cropping and becomes liable to the natural processes of decay" (White, 1928, p. 86). The effect of carbon dioxide treatment here is seen in the better swelling of the fruit.

The commoner root decay organisms have not proved capable of active parasitism of healthy plants. They are frequently present on the roots of plants which have appeared quite healthy during the season and borne a satisfactory crop (Williams, 1929). They have not been definitely identified until the beginning of June (Ebben, 1950).

Another experimental observation, confirming indirectly the trend of root growth just described, is that of watering. In 1929 (Ann. Rept. XV, 1929, 9 and 26-27) watering by buried pipes gave better results than hose watering but it was necessary to cease the application of water from below after the beginning of June, because the lower region of the soil became waterlogged and some yellowing appeared in the foliage. The bottom crop was excellent and there were indications that subterranean watering is of considerable importance at the beginning of the season. Growth in the underground watered plots was superior in every way to that in other plots up to the end of June. This was confirmed in 1930 (Ann. Rept. XVI, 1930, 9 and 19-20), underground watering being beneficial only until the end of May. In an investigation of percolation and the loss of manure applied to glasshouse soils (Owen, 1932) it is noticeable that the volume of drainage water showed a sharp initial peak at the beginning of June.

In the present investigation, the low level of total root length, accompanied, presumably, by dead and dying roots, occurred in June, i.e. at the time when mycological investigations have shown

the first isolations of root rotting organisms and the watering experiments showed an apparent decline in water uptake.

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2. A NOTE ON THE USE OF TENSIOMETERS

By H. R. B. HACK

A. Some Consideration of previous Work

Tensiometers have been in use for measuring soil moisture tension for over 30 years (Gardener, W., *et al.*, 1922; Kornev, B. G., 1924). The instrument consists essentially of a system filled with water, in communication with the moisture in the soil via a porous wall and furnished with a device for measuring the pressure within the system.

The literature on tensiometers will not be discussed here in detail; an indication, however, will be given of present opinion on some of their fundamental characteristics.

Tensiometers have been used in two types of measurement of soil tension:—

(1) The instruments have been inserted in soil, whose moisture content is static or only changing extremely slowly, in order to determine the tension previously attained.

(2) The instruments have been left *in situ* for the measurement of transient tensions. Indication may be required of relatively rapid changes of soil moisture due to the presence of roots of plants actively absorbing water.

(1) Static Soil Moisture Tension

A. L. C. Davidson and R. K. Schofield (1942) mention a lag in response shown by a tensiometer furnished with a mercury manometer. The tension indicated by this instrument was compared with that derived from porous plates which could be used for independent measurement of tension by weighing, since the moisture content/moisture tension relationship had been determined. They conclude: "Why these instruments fail to reach the theoretical limit we do not know, but we suspect that the principle cause is the fall in the moisture conductivity of the soil with rise in suction . . . it appears to be impossible to prevent the release of water into the soil (from the tensiometer cup (H.R.B.H.)) when the suction is high . . . this water materially reduces the suction in a thin layer of soil against the filter."

Some evidence is given showing that the lag of the tensiometer is a function of tension. Below a tension of about 30 cm. Hg a correct value was claimed after about 24 hours.

D. Cronney, J. D. Coleman, and P. M. Bridge (1952) were also probably concerned with static conditions or with very slow changes. They conclude: "When the suction indicated by a tensiometer changes, some transfer of moisture into or out of the porous pot must occur. Similarly, when the instrument is first installed the moisture content of the surrounding material is increased whilst equilibrium is being reached. With a sealed sample, the increase in moisture content would be permanent, and the actual measured suction would be less than the suction present prior to the installation of the tensiometer. For soil in equilibrium with a water table, the water taken into the soil from the porous pot is transferred to the water table and true equilibrium is reached only when this transfer is complete. The suction present in the soil is thus not affected by the presence of the tensiometer. The volume of water which passes through the filter to satisfy a change of suction depends on the diameter of the manometer tube. A narrow tube is essential to rapid response and to reduce the disturbance caused to the moisture content of the soil. Tubes of diameter 0.5 mm. and 1 mm. have been found satisfactory."

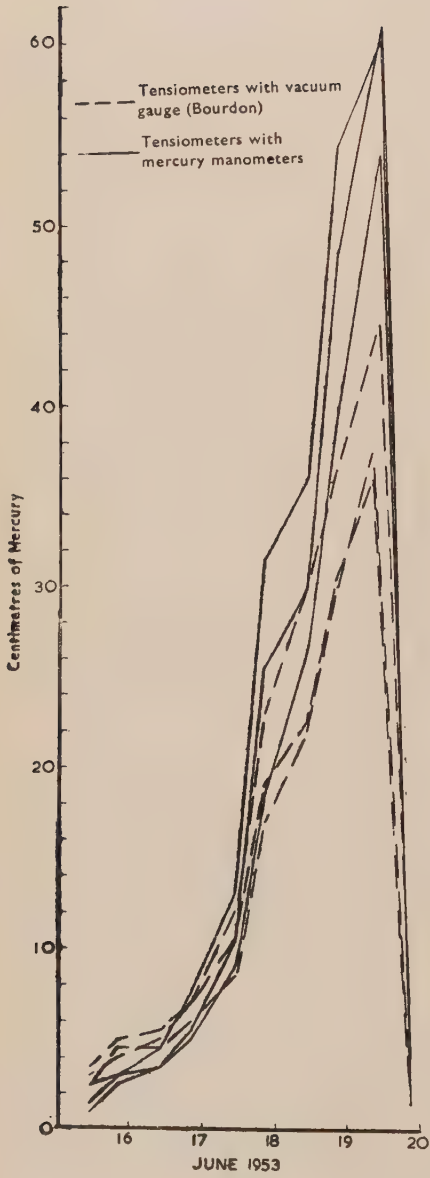


Fig. 1

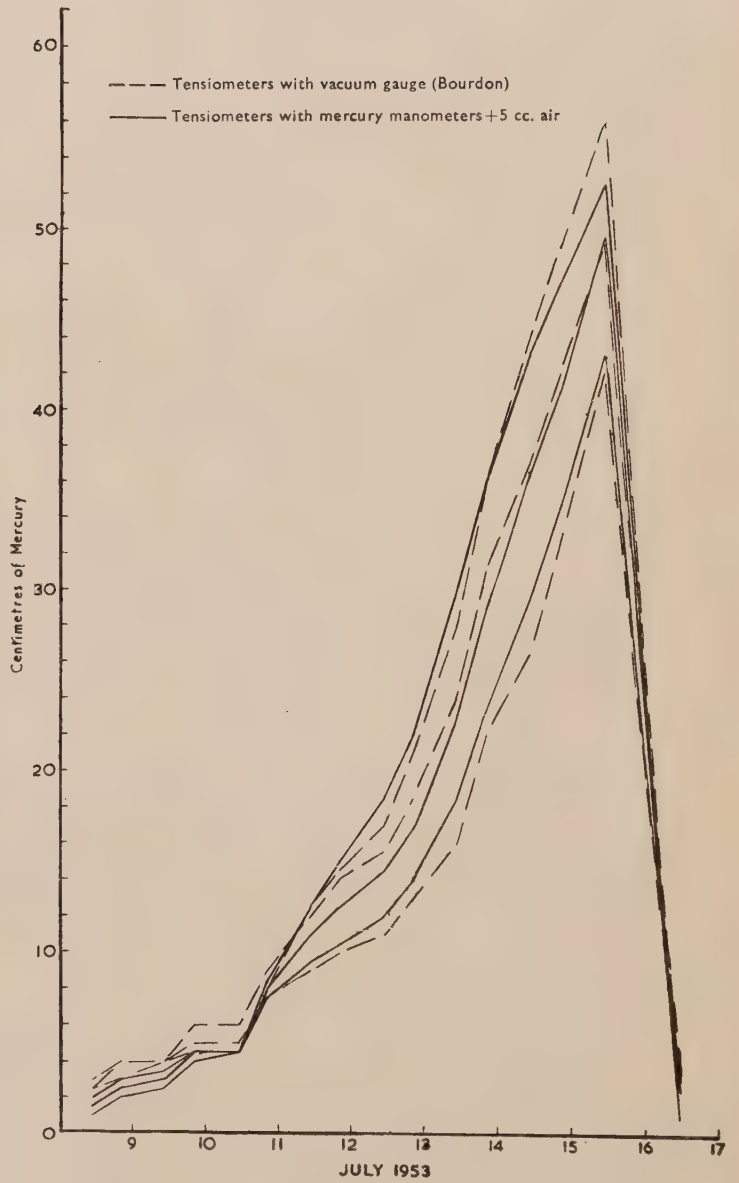


Fig. 2

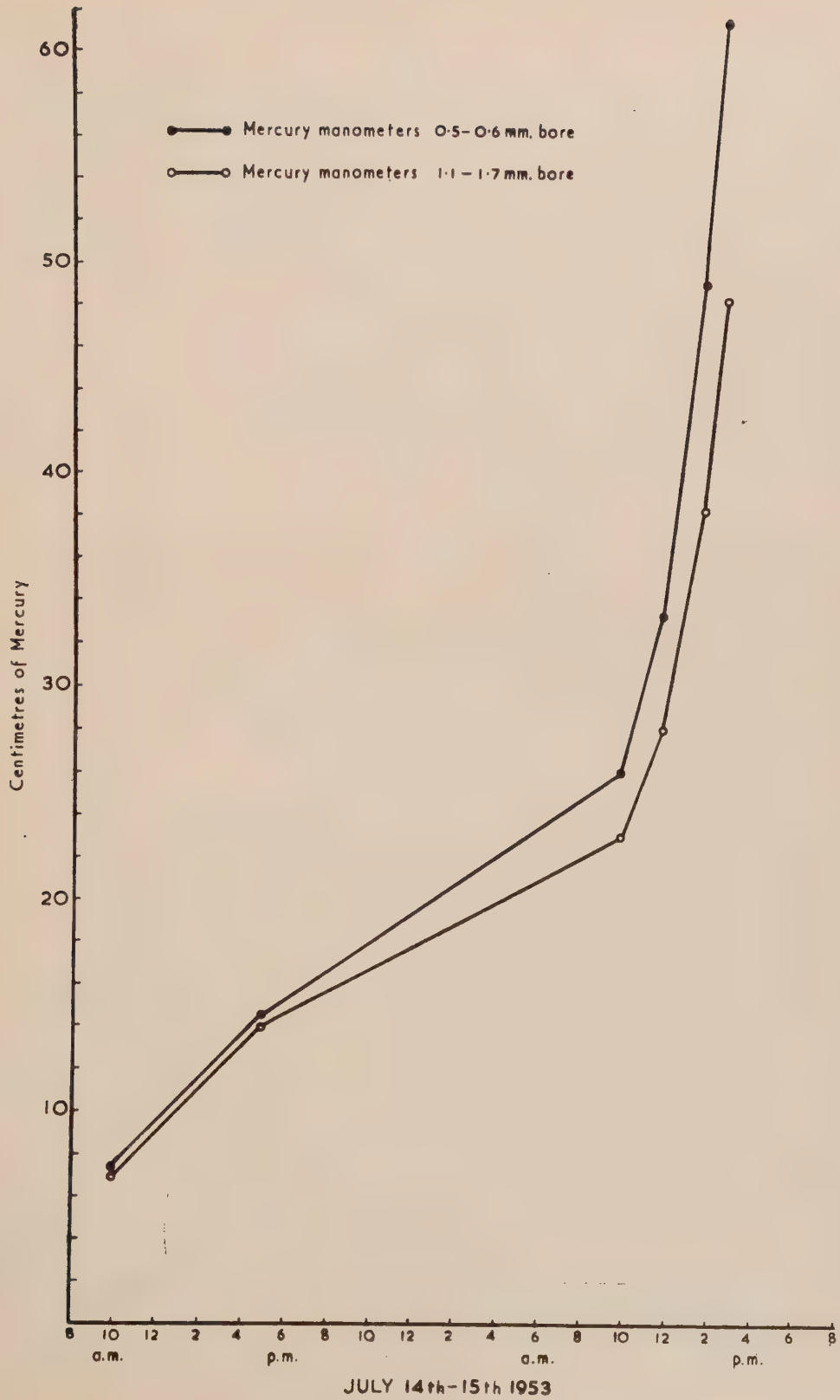


Fig. 3

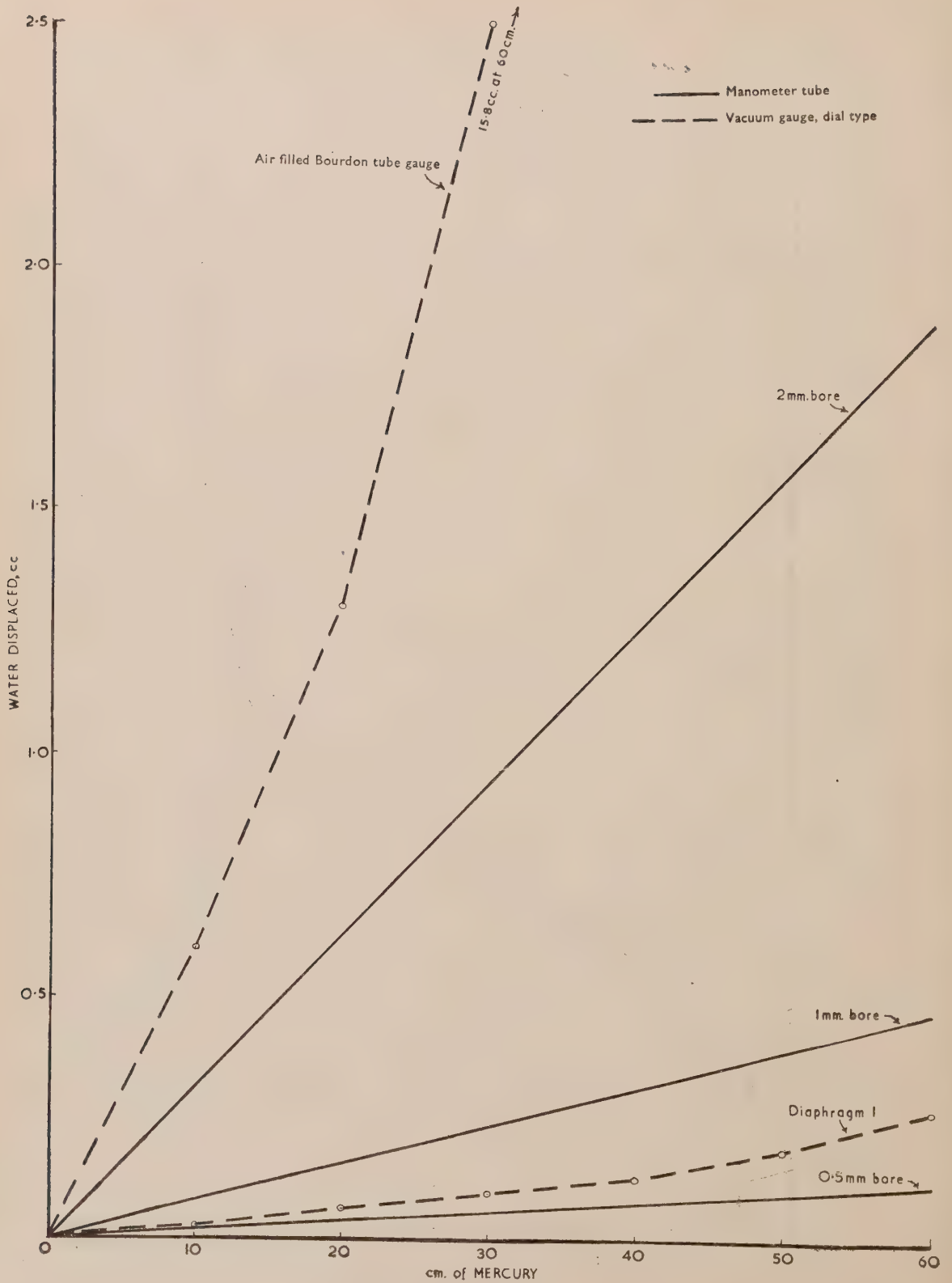


Fig. 4

They do not give data to show the different rates of response of tensiometers having different bore manometers, nor is it shown how far the differences are affected by the tension at which the measurements are being made.

These authors have also developed a modification of L. A. Richards' suction plate apparatus for the rapid measurement of the suction of a sample of porous material. This method involves the use of a vacuum pump to counterbalance the movement of water from the instrument into the soil and prevent a change of moisture content during the test. It was tried by them as a field instrument and was still being developed.

(2) The Measurement of Changing Tension in the Presence of Actively Growing Plants

It might be expected that the water absorption by plant roots might reduce any gradient from the surface of the pot to the main mass of soil due to moisture leaving the instrument. Hitherto no direct evidence seems to have been put forward which would throw light on this problem.

L. A. Richards (1949), who has been especially concerned with irrigation practice and the presence of growing plants, has summarised the important operating characteristics of tensiometers. His general conclusion states: "It is now generally accepted that, over a certain range of soil moisture content, water in a porous cup which is filled and connected to a manometer will come to pressure equilibrium with the soil," with the proviso, "Tensiometer readings are unreliable unless it is known that the unit is substantially filled with water." More specifically he states: "The tension range covered by tensiometers extends from 0 to about 850 cm. of water (= 63 cm. Hg. (H.R.B.H.)) or about 0.85 atmospheres. . . . When the soil moisture tension at the porous cup exceeds 0.85 atmosphere, water is extracted from the tensiometer and the gauge readings become unreliable."

B. Programme of Present Investigations in Tensiometry

In order to establish more clearly the lag to be expected from tensiometers used with growing plants in pots and in borders under glasshouse conditions the behaviour of these instruments is being further investigated.

Investigations have included comparisons of different porosities and sizes of cup. Comparisons have also been made between tensiometers furnished with mercury manometers of different bore and between the use of a Bourdon tube vacuum gauge and a narrow bore mercury manometer for indicating the tension. Records over a period of months from instruments left *in situ* have been made. Some important conclusions are illustrated by the results shown in Figures 1, 2, and 3.

(1) Comparison of Tension Indicating Systems: Bourdon Gauge versus Mercury Manometer

Three tensiometers each furnished with a Bourdon gauge were obtained from a commercial source. Three porous cups, of the same type as used in the commercial instrument and obtained from the same source, were each connected to a mercury manometer of approximately 1 mm. bore.

The tensiometers with Bourdon gauges were placed alternately with those having mercury manometers around a tomato plant growing in a large can of soil ($56 \times 26 \times 26$ cm.). The instruments were placed as nearly as possible at the same depth and at the same distance from the plant. Instruments were filled with boiled water immediately after the plant was watered and observations taken twice a day. The continuous lines of Fig. 1 show readings from the mercury manometers. The broken lines show readings from the vacuum gauges. The lag shown by the latter is significant and large. Before watering the mercury manometers have reached a mean of 59 ± 2 cm. At the same time the Bourdon gauges have attained a mean of only 39 ± 3 cm. As can be seen in the figures the lag increased throughout the run.

It seemed probable that the lag was due to the greater quantity of water leaving the porous cup attached to the Bourdon gauge than that leaving the porous cup with the narrow bore manometer.

By weighing one of the tensiometers attached to a gauge as it evaporated in air it was possible to determine that the same quantity of water was lost for a given increase of tension as would be expected if about 5 cc. of air were present at zero tension. This quantity of air was admitted into each of the three mercury manometer systems. Comparison was then made between readings from the three Bourdon gauges filled, as before, according to the makers' instructions and the three mercury manometers. Results for the subsequent drying cycle of the soil are shown in Fig. 2. The readings from the different instruments are closely similar.

Observations were carried on during the rest of the season, alternating runs with and runs without the addition of air to the mercury manometers, with similar results.

It seems clear that the expansion of air as the tension increases within the tensiometers furnished with vacuum gauges results in sufficient water leaving the system to cause considerable lag when the drying period from zero tension to 65 cm. tension lasts about six days in this soil.

It has been shown from further laboratory tests that there are about 4 cc. of air in the Bourdon tube and connections of the vacuum gauge used. Lag in the tension indicated under the conditions of these drying studies is apparently the result of an inherent characteristic of a tensiometer furnished with this type of air-filled measuring system.

(2) Comparison of Tension Indicating Systems: Mercury Manometers of Different Bore

It is of interest to consider whether lags are to be found when instruments, having a very much smaller water displacement associated with the measuring system, are compared.

Three tensiometers furnished with Doulton P5 filter candles as porous cups and attached to manometer tubes of bore 1.1–1.7 mm. were alternated with three tensiometers furnished with the same type of porous cup and manometers of 0.5–0.6 mm. bore at equal distances from a tomato plant and at equal depth as before. The pots of soil were smaller, having a mean diameter of 25 cm and a depth of 24 cm.

Fig. 3 shows a record from a period of rapid drying over three days. When the mean tension of the narrow bore instruments was 61 ± 3 cm. the mean of the broad bore tubing manometers was 48 ± 1 cm. Lags as large as this occurred only when there was a tension greater than 30 cm. Hg during a period of hot weather. Where rates of change are slower the lag is much less, and when a period of rapid drying is followed by a period of slow change, the tensiometers with broad bore manometers have some opportunity to catch up.

(3) The Displacement of Water from Tensiometers

Data illustrating the water displacement when different measuring systems are employed is shown in Fig. 4.

The Bourdon tube filled with air displaces about 16 cc. for a change of 60 cm. Hg. This point would require the vertical axis extended six times to appear on the figure.

A diaphragm gauge specially designed for simple filling with water in the field (Diaphragm No. 1) has a displacement between that of 0.5 mm. and 1.0 mm. bore manometers. Bourdon tube gauges can be obtained, which when filled with incompressible liquid, have a similar displacement to this diaphragm.

(4) Further Lines of Investigation

- (1) The diaphragm vacuum gauge mentioned is under trial for use where rates of change are relatively slow, as in the greenhouse border.
- (2) A null method for the more rapidly changing tensions such as are found in the study of growth of plants in pots is also under trial. This instrument also records.
- (3) Investigation of variability of soil moisture tension as a function of distance from the tomato plant and position of plant in the border is being continued.

These studies are being related to the diffusivity of moisture in soil which is being investigated by means of the recording null method instrument.

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APPENDIX "A"

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APPENDIX "B" MANURIAL TREATMENT IN TOMATO EXPERIMENTS (Except plots in Appendix C)

House	Plot	Steriliza- tion	BASE TREATMENT					TOP DRESSING						Nutrient Feeding by Solu- feeder		
			Lime	Stable Manure	Hoof and Horn	Bone Meal	Sulphate of Potash	Sulphate of Ammonia	Sulphate of Potash with first Watering	Balanced Mixture	Dried Blood Mixture	Sulphate of Ammonia	Superphos- phate		Sulphate of Potash	Dried Blood
1			1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	5 cwt. per acre	9 applica- tions	None						
3	2 & 5	Formal- dehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	5 cwt. per acre	8 applica- tions							
	1	"	"	"	"	"	"	"	"	"						
	3	Chloro- picrin	"	"	"	"	"	"	"	"						
	4	"	"	"	"	"	"	"	"	"						
	6	"	"	"	"	"	"	"	"	"						
4	4 to 13	Chloro- picrin	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre	5 cwt. per acre	8 applica- tions	None						
		"	"	"	"	"	"	"	"	"						
	1 2 3	"	"	"	"	"	"	"	"	"						
	14	Formal- dehyde	See Appendix "C"	"	"	"	"	"	"	"						
	15	"	"	"	"	"	"	"	"	"						
	16	"	"	"	"	"	"	"	"	"						

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APPENDIX "B" **MANURIAL TREATMENT IN TOMATO EXPERIMENTS** (Except plots in Appendix C)

House	Plot	Steriliza- tion	BASE TREATMENT					TOP DRESSING							Nutrient Feeding by Solu- feeder
			Lime	Stable Manure	Hoof and Horn	Bone Meal	Sulphate of Potash	Sulphate of Ammonia	Sulphate of Potash with first watering	Balanced Mixture	Dried Blood Mixture	Sulphate of Ammonia	Superphos- phate	Sulphate of Potash	
1			1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre		5 cwt. per acre	9 applica- tions	None				
3	2 & 5	Formal- dehyde	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre		5 cwt. per acre	8 applica- tions					
	1	Chloro- picrin	"	"	"	"	"		"	"					
	3	"	"	"	"	"	"		"	"					
	4	"	"	"	"	"	"		"	"					
	6	"	"	"	"	"	"		"	"					
4	4 to 13	Chloro- picrin	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre		5 cwt. per acre	8 applica- tions	None				
		"	"	"	"	"	"		"	"	"				
	1	"	"	"	"	"	"		"	"	"				
	2	"	"	"	"	"	"		"	"	"				
	3	Formal- dehyde	See Appendix "C"	"	"	"	"		"	"	"				
	14	"	"	"	"	"	"		"	"	"				
	15	"	"	"	"	"	"		"	"	"				
	16	"	"	"	"	"	"		"	"	"				
5	1	Chloro- picrin 40 lbs. per acre	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre	10 cwt. per acre		5 cwt. per acre	7 applica- tions	None	1 applica- tion			
	2	"	"	"	"	"	"		"	"	"				
	3	"	"	"	"	"	"		"	"	"				
	4	"	None	"	"	"	"		"	"	"				
	5	"	"	"	"	"	"		"	"	"				
	6	"	1 ton per acre	"	"	"	"		"	"	"				
7		Steam					10 cwt.								

8	1	Steam	1 ton per acre					per acre	6 applica- tions	1 applica- tion	1 applica- tion					
	4	"	"					10 cwt. per acre	6 applica- tions	1 applica- tion	1 applica- tion					
	6	"	"					"	"	"	"					
	7	"	"					"	"	"	"					
	2	Chloro- picrin	1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre		10 cwt. per acre	"	"	"					
	3	"	"	"	"	"		"	"	"	"					
	5	"	"	"	"	"		"	"	"	"					
	8	"	"	"	"	"		"	"	"	"					
9	1	Steam	1 ton	None	None	None		10 cwt. per acre	6 applica- tions	1 applica- tion	1 applica- tion					
	2	"	"	"	"	"		"	"	"	"					
	3	"	"	"	"	"		"	"	"	"					
	4	"	"	"	"	"		"	"	"	"					
	5	"	"	"	"	"		"	"	"	"					
	6	"	"	"	"	"		"	"	"	"					
	7	"	"	"	"	"		"	"	"	"					
	8	"	"	"	"	"		"	"	"	"					
	9	"	"	"	"	"		"	"	"	"					
	10	"	"	"	"	"		"	"	"	"					
	11	"	"	"	"	"		"	"	"	"					
	12	"	"	"	"	"		"	"	"	"					
	13	"	"	"	"	"		"	"	"	"					
	14	"	"	"	"	"		"	"	"	"					
	15	"	"	"	"	"		"	"	"	"					
	16	"	"	"	"	"		"	"	"	"					
10		Steam	1 ton per acre					10 cwt. per acre	6 applica- tions	1 applica- tion	1 applica- tion					
11	1		1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre		10 cwt. per acre	6 applica- tions	2 applica- tions						
	2		"	"	"	"		"	"	"	"					
	3		None	"	"	"		"	"	"	"					
	4		"	"	"	"		"	"	"	"					
12	1		1 ton per acre	15 tons per acre	10 cwt. per acre	10 cwt. per acre		10 cwt. per acre	None	2½ cwt. per acre				None		
	2		"	"	"	"		"	"	"	"			"		
	3		None	"	"	"		"	"	"	"			"		
	4		"	"	"	"		"	"	"	"			"		
Rose House		Steam	1 ton per acre	None	None	None		10 cwt. per acre	7 applica- tion					"		

APPENDIX "C"

MANURES APPLIED IN PLOTS 1-3 AND 14-16 IN TOMATO HOUSE 4

Plot	Title	Base Manure in Lbs. per sq. yds.				*Top Dressing in Lbs. per sq. yds.		
		Lime	Stable Manure	Super- phos- phate	Sulphate of Potash	Super- phos- phate	Sulphate of Ammonia	Sulphate of Potash
1	Complete Artificials (I) less Nitrogen	1.0	—	0.4	0.1	0.5	—	0.2
2	Unmanured	—	—	—	—	—	—	—
3	Complete Artificials	1.0	—	0.4	0.1	0.5	0.2	0.2
8	Complete Artificials with Dung	1.0	7	0.4	0.1	0.5	0.2	0.2
9	Complete Artificials less Phosphate	1.0	—	—	0.1	—	0.2	0.2
10	Complete Artificials less Potash	1.0	—	0.4	—	0.5	0.2	—

* The Top-dressing was applied in eight equal instalments.

APPENDIX "D"

DATES OF CULTURAL OPERATIONS, 1953

Crop	Sown	Potted into 60's	Potted into 32's	Planted out in Borders	First top Dressing	First Fruit Picked	Last Feed Applied	Last Fruit Picked
Tomatoes	1.1.53	3.2.53	—	6.3.53	1.5.53	23.5.53	30.7.53	27.10.53
Cucumbers	15.1.53	—	6.2.53	24.2.53	8.4.53	30.3.53	18.8.53	28.9.53

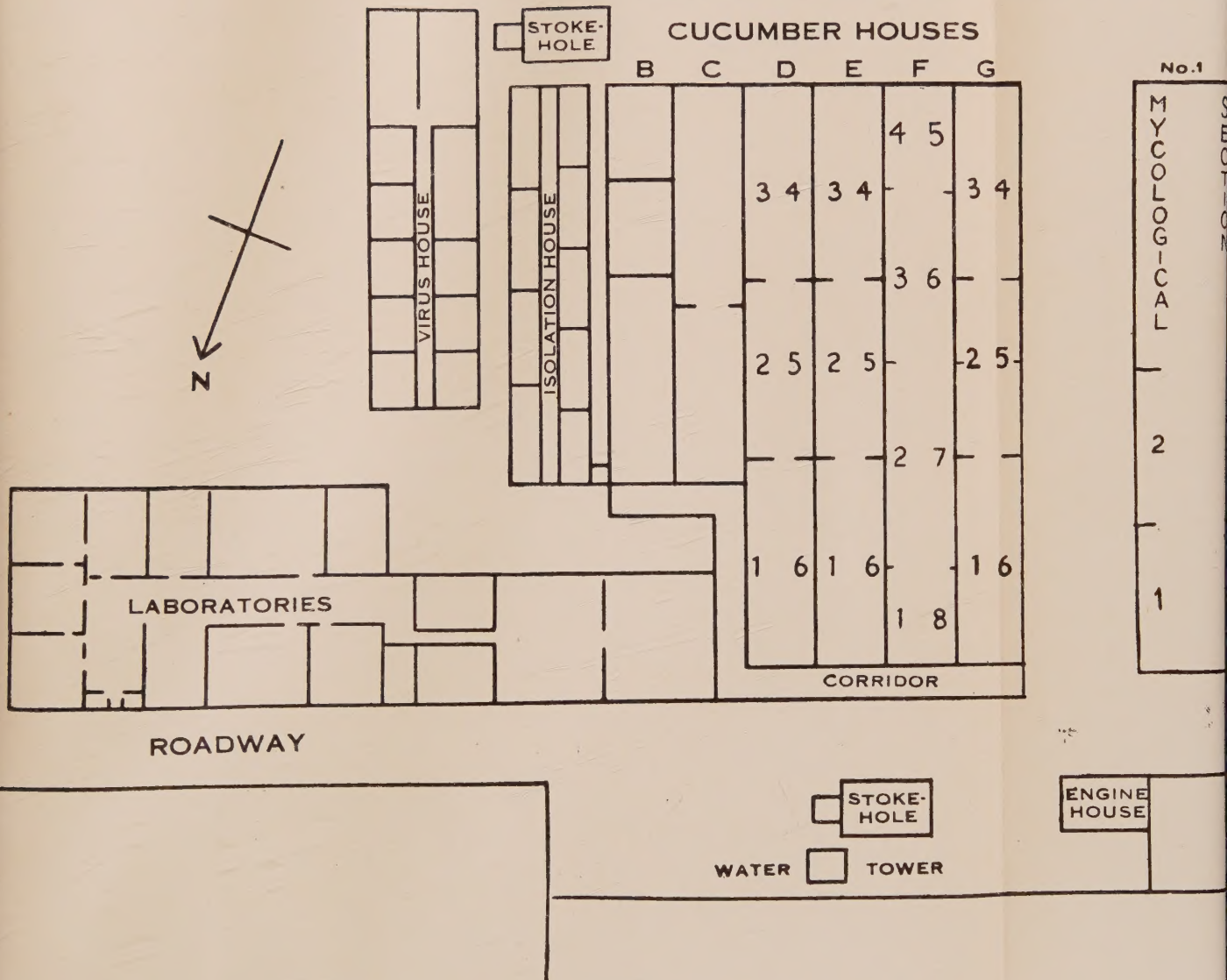
APPENDIX "E" METEOROLOGICAL RECORDS, 1953

Month	Air Temperatures										Rainfall			Mean Soil Temperatures at 9 h. G.M.T.				Hygrometer at 9 hrs. G.M.T.				No. of Days Fog at 9 hrs. G.M.T.	Bright Sunshine	
	Mean		Absolute Maximum		Absolute Minimum		* ° F. ° N.	Absolute Grass Min.		Total ppt.	No. of days ppt.	Greatest Fall		4 ins. ° F.	8 ins. ° F.	2 ft. ° F.	Dry Bulb ° F.	Depress. of Wet Bulb ° F.	Relative Humidity %	Dew Point ° F.				
	Max.	Min.	Temp.	Date	Temp.	Date		Temp.	Date			Amt.	Date											
	° F.	° F.	° F.		° F.		° F.		° F.		Ins.	Ins.	Ins.	° F.	° F.	° F.	° F.	° F.	%	° F.				
JANUARY	42.6	33.7	57	29th	26	{ 20th 21st	18	20	21st	0.91	9	40	5th	36.3	37.1	40.0	36.8	0.8	92.2	34.8	10	30.4	1.0	
FEBRUARY	45.8	34.6	59	27th	21	7th	16	13	7th	1.65	8	52	9th	33.8	38.0	39.8	38.8	1.8	84.1	34.4	5	68.3	2.4	
MARCH	53.5	33.5	71	25th	25	16th	21	13	17th	0.58	4	28	30th	38.2	39.6	42.0	40.4	2.0	83.3	35.5	5	123.1	4.0	
APRIL	55.9	39.2	67	{ 21st 22nd	30	11th	11	20	8th	2.52	17	92	30th	45.6	45.4	46.6	48.0	3.8	71.7	39.1	1	159.7	5.3	
MAY	65.4	46.6	85	25th	34	11th	5	24	11th	1.27	10	32	15th	56.9	55.7	53.9	57.2	4.8	71.2	47.7	0	221.9	7.2	
JUNE	67.1	50.6	80	{ 26th 29th	42	{ 4th 6th	0	34	8th	1.89	13	75	15th	58.9	57.6	57.2	58.2	3.7	85.8	56.3	0	142.5	4.8	
JULY	70.5	53.1	81	5th	48	{ 11th 16th 25th	0	38	16th	2.88	18	65	31st	63.3	62.0	61.9	62.5	4.6	75.4	54.1	0	194.5	6.3	
AUGUST	75.0	52.6	91	12th	42	1st	0	35	27th	1.59	10	48	19th	64.1	63.1	62.8	64.3	5.6	70.5	54.5	0	227.2	7.3	
SEPTEMBER	67.8	48.1	78	{ 1st 8th	40	{ 11th 29th	1	30	11th	1.84	14	34	19th	56.1	56.5	59.6	58.3	3.5	79.2	51.6	3	177.1	5.9	
OCTOBER	59.0	43.9	72	1st	31	31st	11	23	31st	2.99	12	84	12th	50.4	51.6	54.9	50.2	1.3	90.9	47.6	10	75.1	2.4	
NOVEMBER	52.7	41.2	59	{ 15th 28th	30	{ 3rd 5th	8	20	3rd	1.01	10	49	1st	44.9	46.1	49.9	47.0	1.6	88.1	43.7	10	44.0	1.5	
DECEMBER	50.2	41.3	61	4th	29	21st	7	23	21st	0.55	8	27	30th	44.1	45.2	48.3	44.9	0.7	93.1	43.5	11	29.1	0.9	
TOTAL							98			19.68	133										55	1492.9		

* Grass Min. 30.4° F. or less.

† Visibility 440 yards or less.

DIAGRAM SHEWING ARRANGEMENT



OF EXPERIMENTAL PLOTS, 1953

TOMATO HOUSES

